OCTOBER 5, 1967 • VOL. 22 • NO. 3 • A SCHOLASTIC MAGAZINE

SENIOR SCIENCE

For Classes in Biology, Chemistry, Physics, Earth and Space Science

The Search for the Perfect Vacuum

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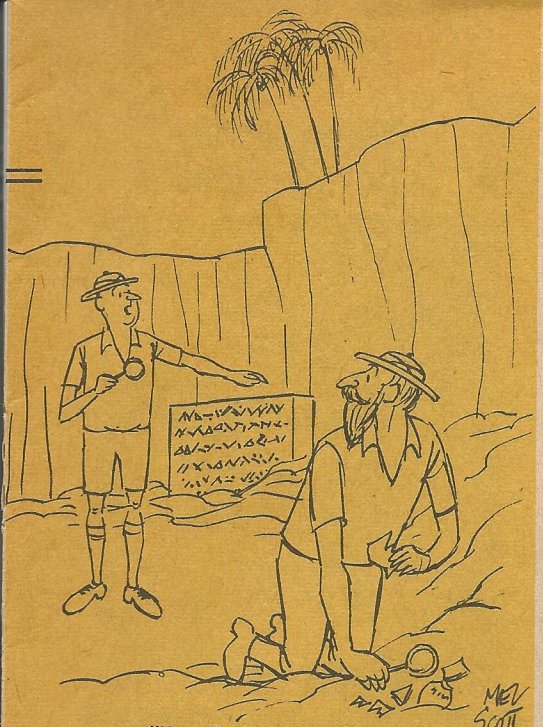

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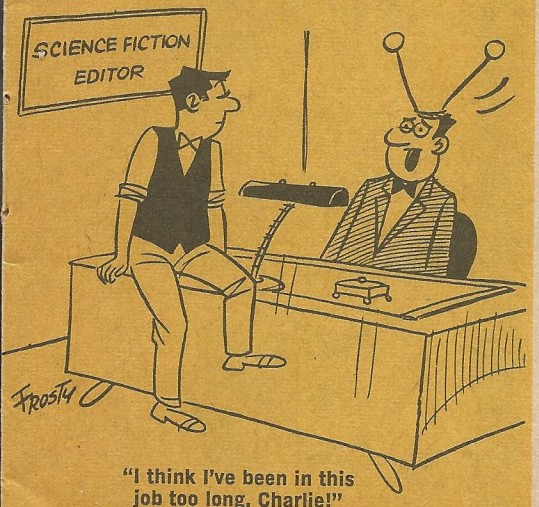

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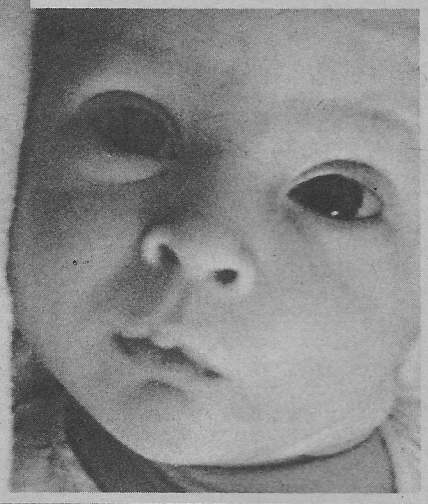

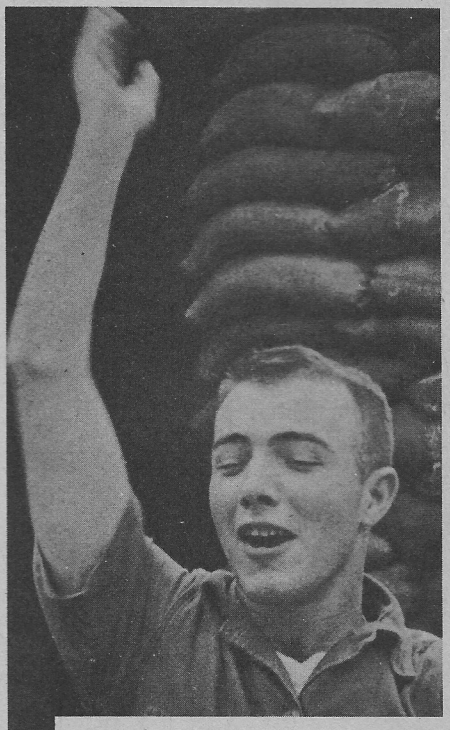

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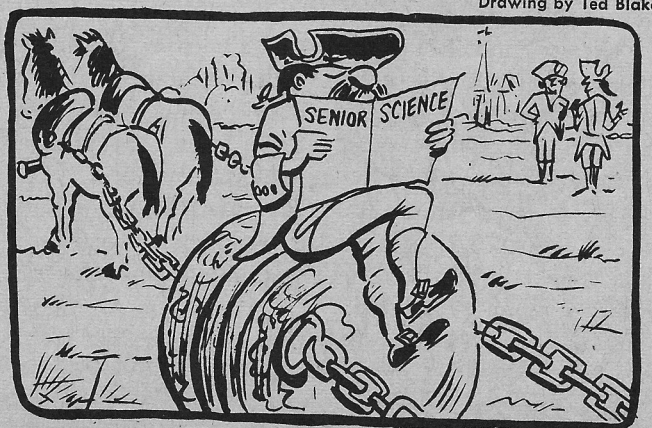
Cover photo: North American Nebula in Cygnus, from the Palomar Observatory

Our Front Cover

The ultra-high vacuum of outer space has become a tantalizing target for modern science. For one thing, we must simulate space conditions here on Earth to test space vehicles and materials, for high vacuum has strange effects on matter. And creation of ever-better vacuums in the research laboratory will help unravel some of the tangled mysteries of physics.

Drawing by Ted Blake



MICROBES AT WORK

DID YOU know that for thousands of years men have "domesticated" microbes – organisms so tiny they can't be seen without a microscope? In fact, one group of these minute organisms, yeasts, have been called the world's oldest cultivated plants!

Precision models of a bakery and a brewery have been found in an ancient Egyptian tomb – evidence that bakers and brewers were already employing yeast 4,000 years in the distant past. Furthermore, the biblical *Book of Exodus* tells us that when the Hebrews fled Egypt for the Promised Land they were forced to subsist on *unleavened bread* (flat bread that resembles a thick cracker). How come? The problem was merely a matter of missing microbes.

If left to itself, bread dough doesn't rise. But when a bit of yeast, or *leaven* (from the Latin word meaning "rise"), is added to the doughy mixture, carbon dioxide is produced. Bubbles of the gas begin forming within the dough; these bubbles make the dough rise. Thus a baked loaf comes out of the oven light and fluffy. When the Hebrews fled Egypt, they were unable to take along a yeast "balm" (a colony of living cells). So the exodus was marked by the eating of unleavened bread.

Yeasts also play an important role in the production of alcoholic beverages, such as beer and wine. Because bubbles are formed in the liquids by the action of the microbes, the brewer's process goes by the name *fermentation* (from a Latin word that means "to boil").

Since the dawn of history, man has baked a mountain of fluffy loaves and has fermented oceans of beverages.

Courtesy Switzerland Cheese Assoc., Inc.

But only in modern times did he recognize that a living organism was responsible for the processes of leavening and fermentation.

The first man to *see* a yeast cell was Anton van Leeuwenhoek, the founder of the science of microscopy. Van Leeuwenhoek ground very small, near-perfect lenses that clearly magnified objects up to 200 times actual size. He first spotted yeast cells in 1680, when he examined fermented beer with a single lens (called a *simple microscope*). He didn't guess, however, that they were tiny units of life that produced alcohol.

Nor did a whole line of microscopists who followed van Leeuwenhoek realize that yeasts cause fermentation. But then a French scientist, Charles C. de la Tour, made a signal discovery.

Sour Grapes

Having put together an extremely good *compound microscope* (more than one lens), he zeroed in on some yeast cells and watched them in the act of reproducing themselves. Thus, from de la Tour's time, men knew the microbes were alive.

In the middle of the 19th century, the wine industry of France found itself in difficulties that were to lead to one of the most significant breakthroughs in the history of science. Traditionally, wine is set to age following completion of the fermentation process. But the wine suddenly started turning sour by the caskful, so sour, in fact, that no one would drink it. French wine-makers, or *vintners*, panicked. Facing ruin, they called upon a brilliant young French scientist to investigate the problem.

The scientist's name? Louis Pasteur. Young Pasteur lost no time. He began peering through the microscope at both good and sour wines. He found that both contained the "domesticated" yeasts. But the sour wine contained, in addition, a "foreign" microbe. It seemed to Pasteur that the unfamiliar organisms might be the cause of the souring.

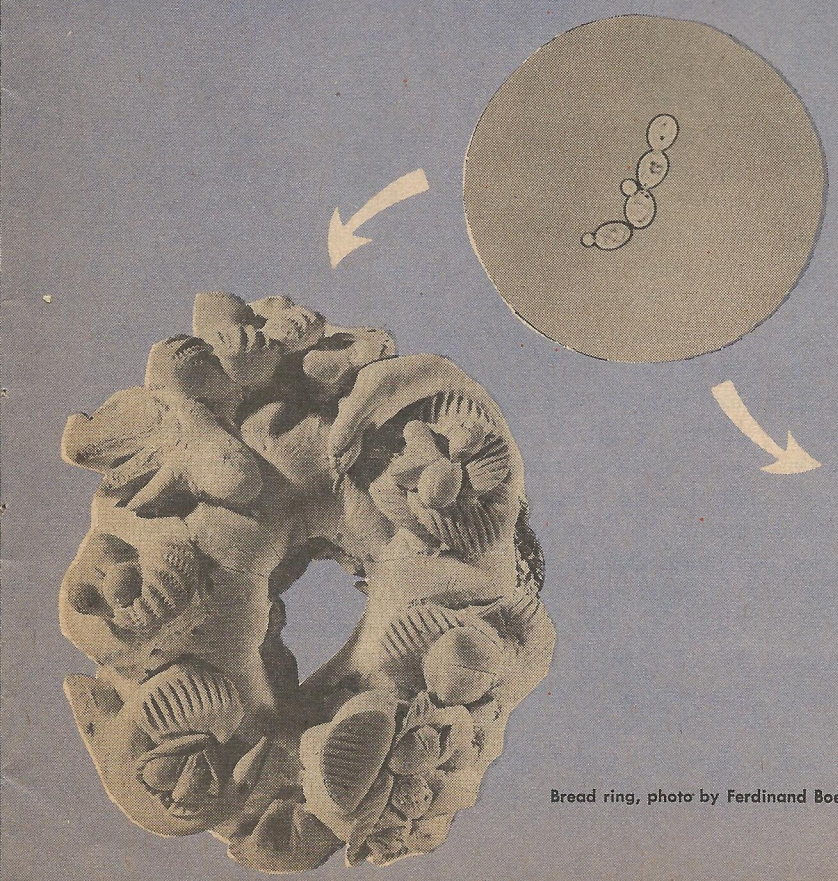
He therefore recommended to the vintners that they try heating all wines *after* the fermentation process. With heat, they could kill off the tiny living organisms — both the familiar yeasts and the unwanted microbes he suspected were turning the fermented wines sour during the aging process.

An anxious wine industry tried Pasteur's recommendations. It worked. Wines stopped turning bad! The now-familiar heating process, called "pasteurization," has subsequently been used to purify many products, from milk to beer.

Successful as he was, Pasteur never knew that his familiar yeasts actually did the work of converting grapes into wine. This discovery was made almost by chance in Germany, at the turn of the century. There, two brothers, Hans and Eduard Buchner, engaged in medical research, decided to make cell-free extracts of yeast for laboratory use.

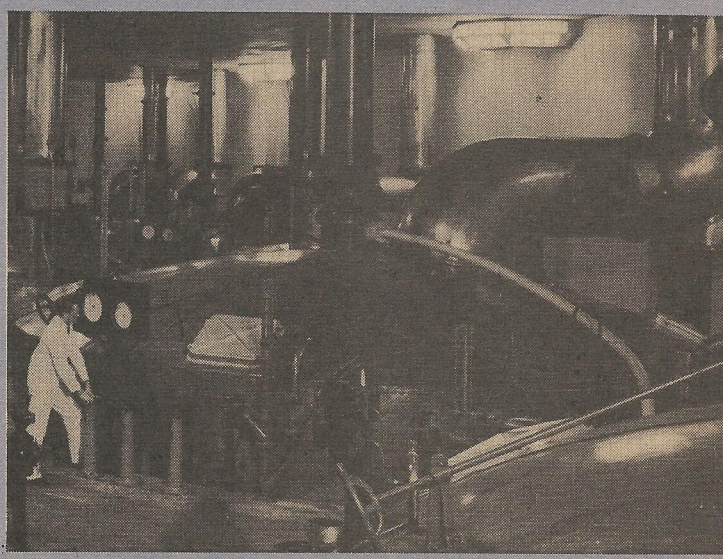
The brothers Buchner first made a paste of ground-up yeast cells and fuller's earth, then squeezed the yeast

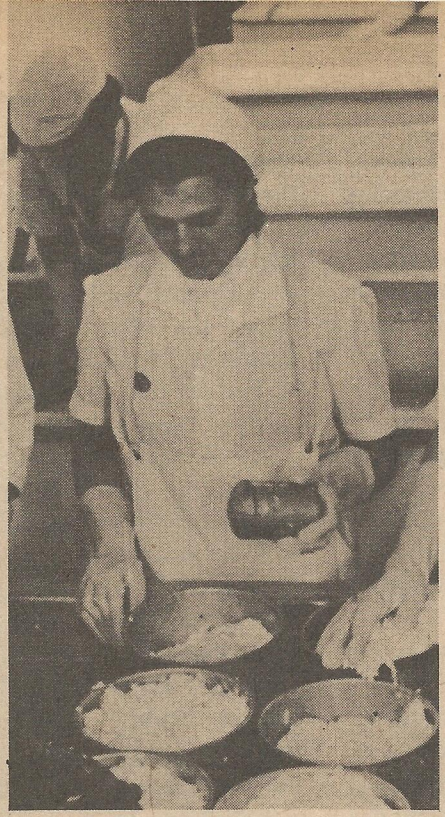
Continued on next page



Bread ring, photo by Ferdinand Boesch

Yeast cells are seen reproducing by budding process. Yeasts are called "world's oldest cultivated plants." Grown on sugar, they produce CO_2 and alcohol as by-products. CO_2 makes the baker's bread (here, a wedding bread from Crete) rise; the alcohol evaporates in the oven. Men also use yeasts to ferment beverages, as in beer brewery.





Courtesy Roquefort Association

Links in Roquefort cheese chain: (1) sheep (at left) supply distinctive milk; (2) lab technician injects mold Penicillium Roqueforti **into cheese; (3) cheeses are then stored in cool caves, allowing mold to work its flavorful biological magic.**

Microbes at Work *continued*

juices from this paste. Next, they mixed the yeast extract with a preservative. The preservative happened to be a highly concentrated solution of sugar. What happened next astonished them. The mixture suddenly began bubbling and frothing – fermenting! They realized that fermentation must be caused by the juices located *inside the walls* of living yeast cells. (Later, all substances that promote organic chemical reactions came to be known as *enzymes* – from a Greek word meaning "in yeast.") For the first time, men recognized that it was the tiny microbes themselves that broke down the sugars of fruits and grain malts to produce alcohol.

Microbiologists now know that these tiny organisms obtain their energy by breaking down sugars into simpler substances. Sugars are carbohydrates – their molecules contain atoms of carbon, hydrogen, and oxygen. In the presence of oxygen, the yeasts convert sugars into carbon dioxide and water. With oxygen absent, the yeasts ferment sugars into carbon dioxide and alcohol. Obviously, brewmasters are interested in the alcohol as an end product of yeast metabolism. A baker benefits from the CO_2 gas, which raises and softens his dough. (The alcohol produced inside the dough by the yeasts evaporates in the oven.) But both men are beneficiaries of the metabolism of the microbes.

Yeasts are single-celled fungi that lack chlorophyll. They are thus unable to make use of the sun's energy to manufacture their own food sugars by the process of photosynthesis. (This production of sugars from water and carbon dioxide occurs only in green plants.) So these "domesticated microbes" are parasites – little "factories" that use the raw materials of other plants to turn out their finished products.

A yeast cell measures about four ten-thousandths of an inch in diameter, and would tip the scales at only a ten-billionth of a gram. Under the best microscopes, the cells appear either spherical or egg-shaped. Yeasts are found almost everywhere in nature – in the sea, adrift on the air, in the soil, and even on human skin! However, the microbes thrive on sugars.

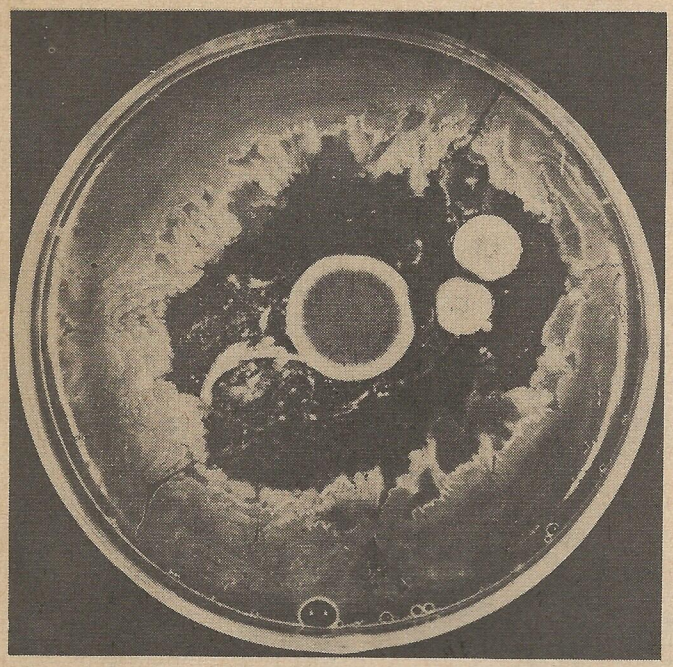
Budding

Anyone can establish a colony of yeasts by exposing the bruised skins of sweet fruits such as grapes or peaches to the air for several days. Colonies will take hold in an opened jar of jam or sweet preserves. You'll recognize the familiar feathery white film of cells on sight. This film is called a "bloom."

Although most modern European vintners still rely on the natural bloom of the grape to provide the yeasts for fermentation, American wineries pasteurize the broth – killing off the natural blooms. Then winemasters add selected strains of yeasts to achieve wines of the desired qualities. The European method is more traditional; the American method offers more standardized "quality control."

British microbiologist Anthony H. Rose is an expert on yeasts. Recent studies of reproduction by yeast cells, says Dr. Rose, have led to an understanding of the processes by which many lower organisms reproduce.

One method by which yeasts reproduce entails the growth of a *bud* or swelling from the cell wall. In time,



Merck & Co., Inc.

Penicillium notatum, **of same family of molds as** P. Roqueforti, **acts as antibiotic. Mold is seen killing surrounding bacteria.**

this bud becomes a new and separate organism. (Yeasts sometimes also reproduce sexually.)

Scientists wondered: What makes the bud extend from the cell wall? According to Dr. Rose, studies now show that the yeast cell internally manufactures a *reducing agent* — a chemical capable of breaking down the protein structure of its own cell wall. Says Dr. Rose, "It would seem, therefore, that reduction of the cell-wall proteins temporarily softens a portion of the wall, whereupon internal pressure within the cell produces the blowout and subsequent bud."

Today, other well-managed "domesticated microbes" produce an impressive array of products for man. Common molds, such as *Penicillium notatum*, and tiny soil-dwelling microbes, such as *Streptomyces griseus*, produce compounds that kill harmful bacteria and are used medically as antibiotic drugs. They yield, respectively, *penicillin* and *streptomycin*.

Bacteria figure importantly in the preparation of many foods. Milk is turned into sour cream, yogurt, and cheese with their help. The processing of pickles, sauerkraut, and olives also depends on bacterial action. Farther out uses for bacteria include the generation of electricity from organic fuels — even from sewage!

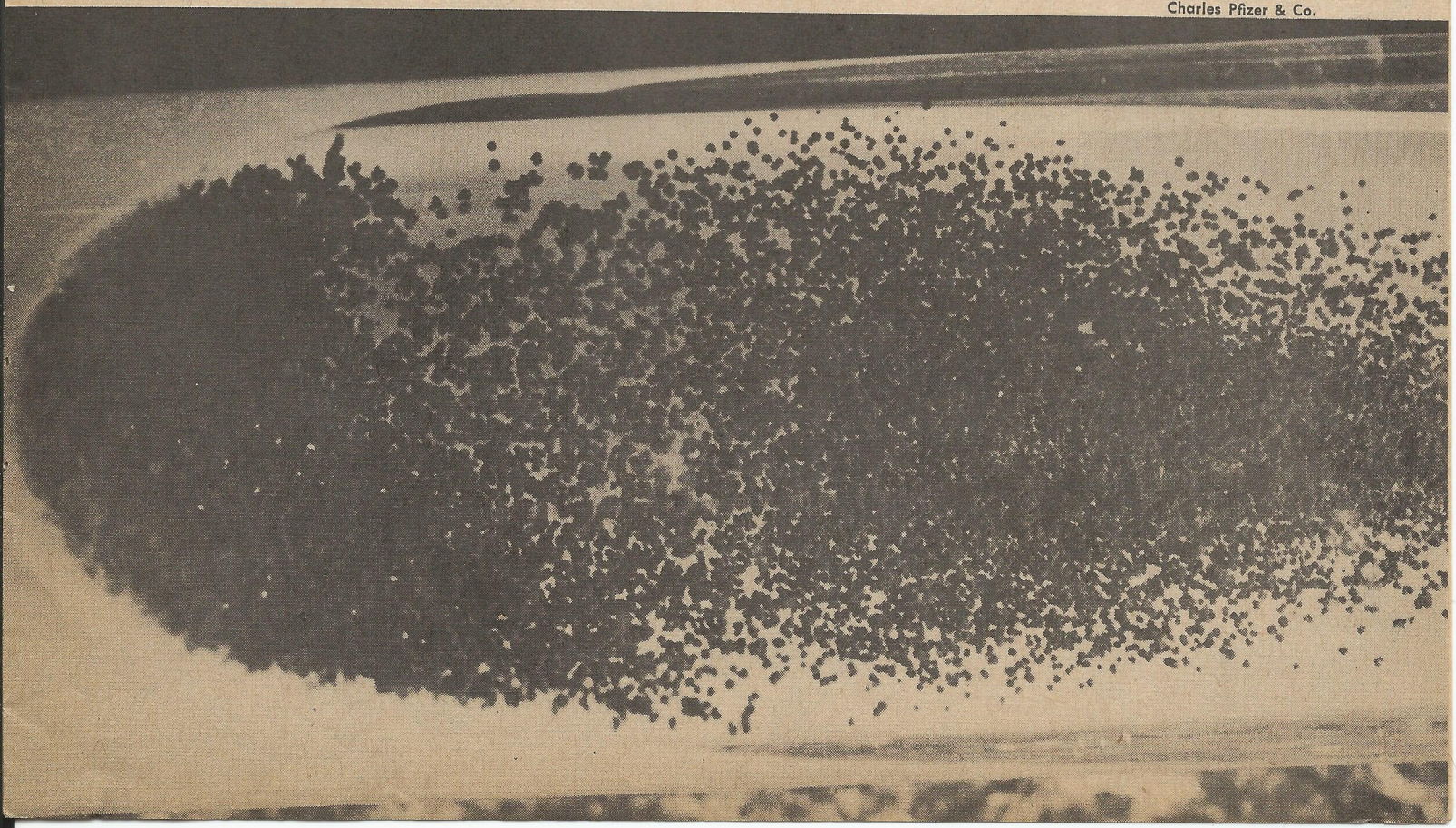
Tomorrow's most important contribution by man's microbe allies may be high-protein foods for a starving world. (See "Harvest of Hunger," *Senior Science*, September 28, 1967.) Yeasts grow on carbon-rich petroleums as they do on sugar. The only difference is that they manufacture protein, rather than alcohol and CO_2. In experimental programs conducted by the British Petroleum Company, microbes thriving in crude oils have yielded high-protein flours that can be prepared in the form of a juicy, tasty, if artificial, beefsteak!

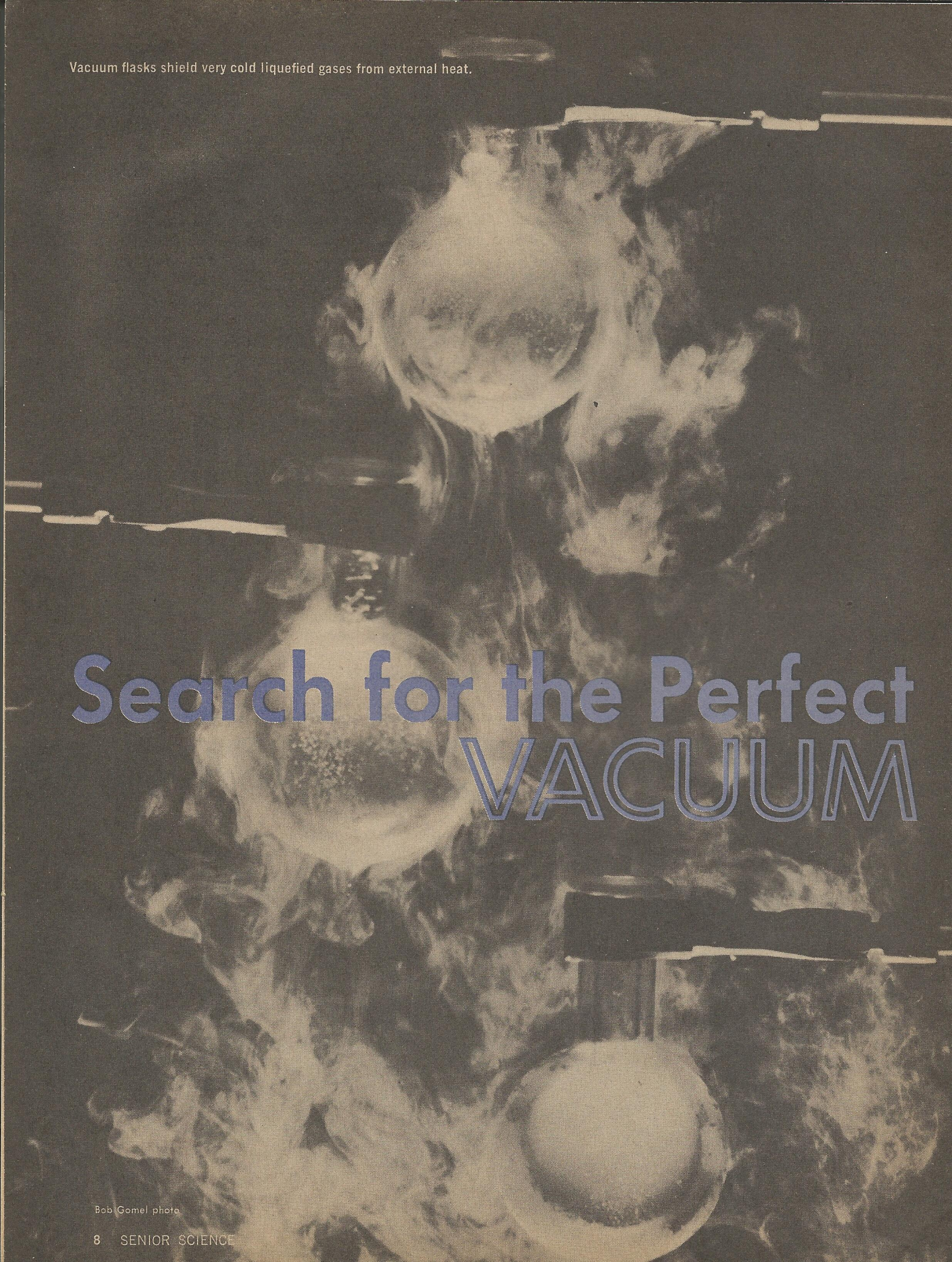
Future "cowpunchers" may be uttering the cry "get along little microbe!"

— JOHN SPEICHER

Black bread mold, Aspergillus niger, **is used to produce citric acid. Citric acid now helps in recovering oil from wells.**

Charles Pfizer & Co.

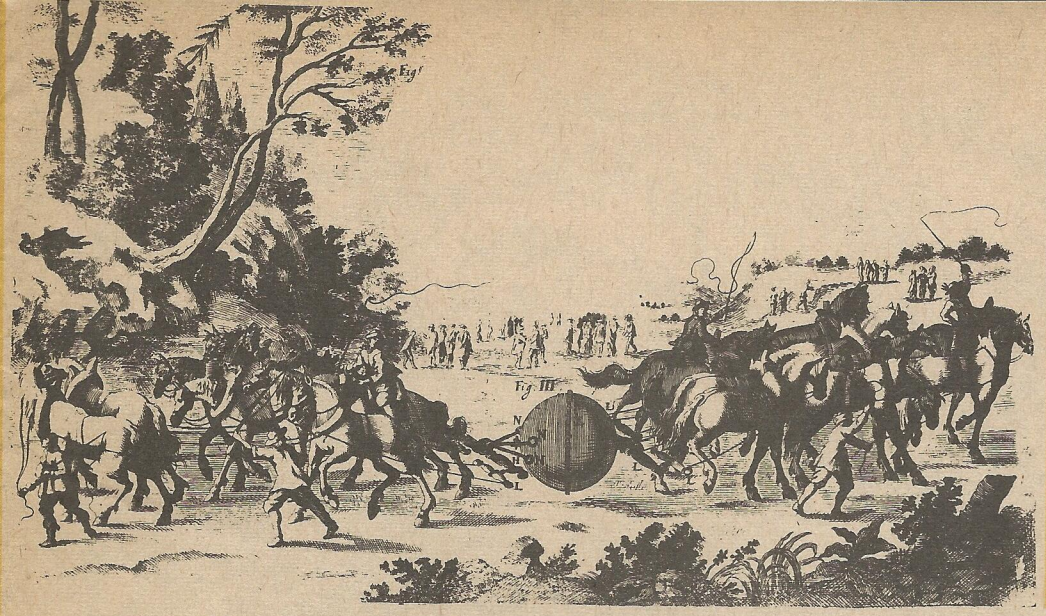


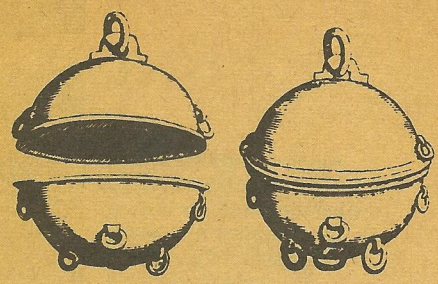


Vacuum flasks shield very cold liquefied gases from external heat.

Search for the Perfect VACUUM

Bob Gomel photo





Left: Sixteen horses could not pull apart the famous Magdeburg hemispheres. German scientist Otto von Guericke used his newly invented vacuum pump to remove air from the hemispheres, and staged this impressive demonstration in 1654. Above: Detailed drawing of hemispheres is shown. Question: What held the hemispheres together? The Bettman Archive

FOR CENTURIES scientists have toiled in a never-ending search for *absolutely nothing* — and have yet to achieve their goal. In fact, these researchers are likely to be unsuccessful in the future.

What might seem a big fuss over nothing is actually a serious task — the search for more and more perfect *vacuums*.

Offhand, you might think the problem is childishly simple: Merely remove everything — including all the atoms and molecules of air or some other gas — from a container, and you've got a vacuum. Sounds easy as pie, doesn't it? But more than one scientist has reached for the aspirin bottle trying to do it. Let's look into this scientific headache.

A logical way to make a vacuum is to pump the air out of an airtight container — we'll call it a *chamber*. So it is not surprising that the first vacuum pumps were very much like bicycle pumps. The only real difference was that such pumps were used in reverse: They were made to *remove* air from a chamber rather than cram air into it.

Many school laboratories have such bicycle-type vacuum pumps — known as *piston* pumps. They work by pulling a piston through a hollow cylinder. Whether they are used to pump air in or to pump air out depends on the arrangement of valves in the pump.

When air is pumped out of a chamber, it has to be pumped *to* some other place. This other place is usually the atmosphere outside the pump. And there's the problem. For the outside air is under *pressure* — defined as a force exerted on a given area. This *atmospheric pressure* exerts a force of 14.7 pounds per square inch at sea level.

As you probably know already, atmospheric pressure

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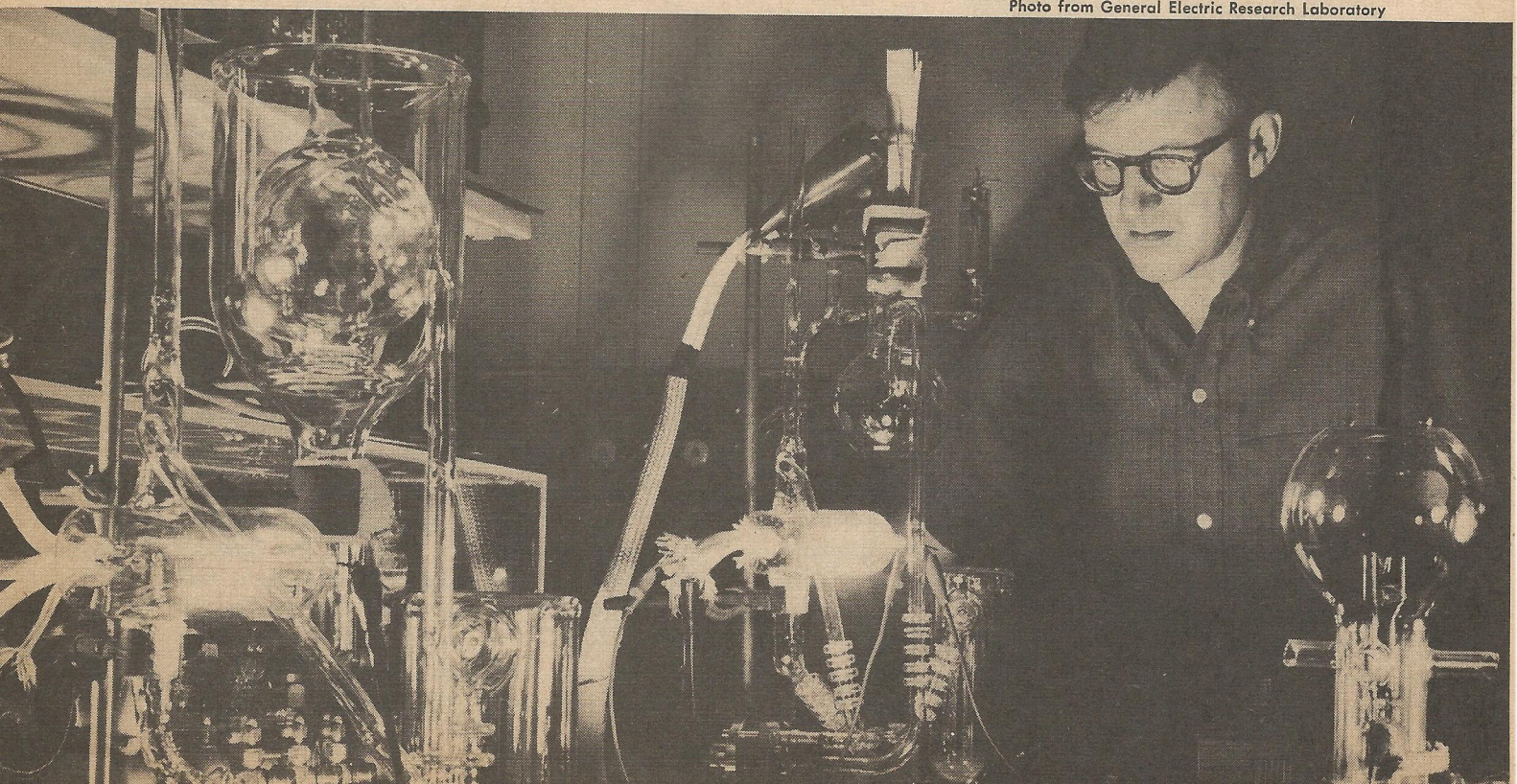
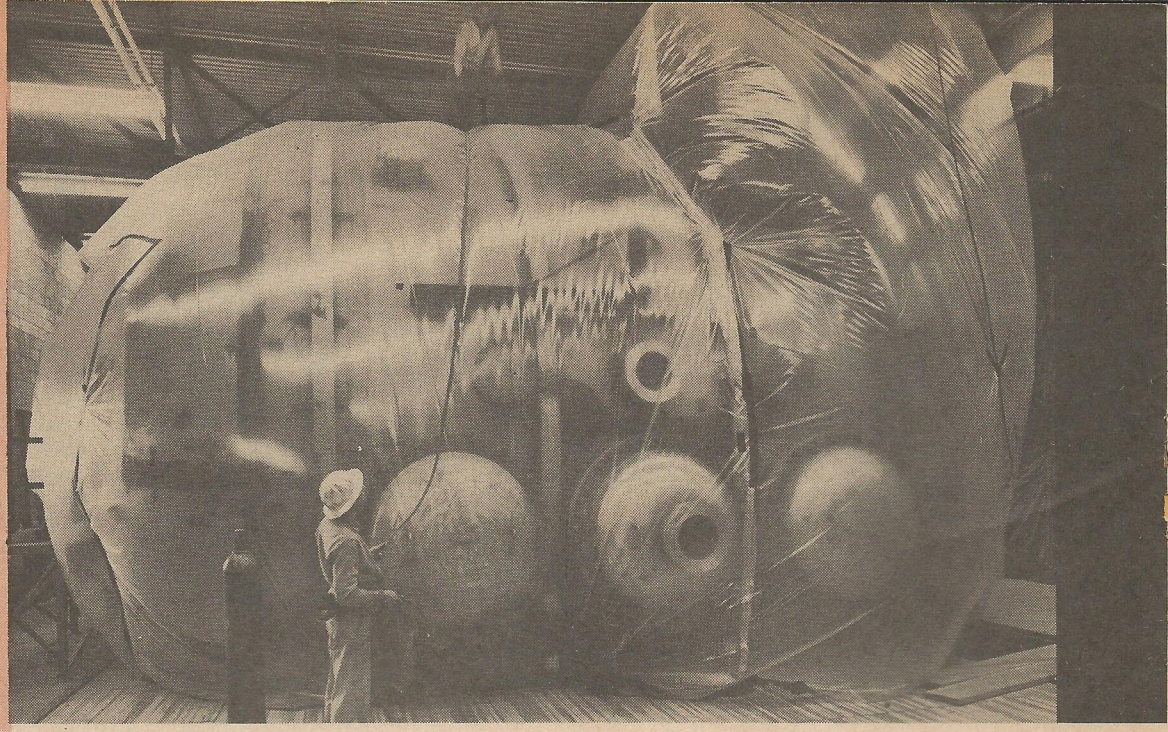
High vacuums are used to study metal surface behavior. Reactions ordinarily occurring in a billionth of a second are slowed down. Photo from General Electric Research Laboratory





Bagged in polyethylene is a high-vacuum chamber used for testing satellites and space capsules. Chamber is used to simulate atmosphere 246 miles above the Earth. Bag is inflated with helium. Scientists will analyze material pumped out of chamber for traces of helium. Object: to test the chamber for leaks.

Bendix Corporation photo

Search for the Perfect Vacuum *continued*

is a consequence of the deep ocean of air that surrounds the Earth. In other words, the 14.7 pounds is the weight of a column of air having a one-inch-square cross section, and stretching from sea level to the fringes of outer space.

Maybe this doesn't sound like much. But did you ever try working against air pressure? You do so whenever you operate a piston vacuum pump. At first, it doesn't appear to be hard work. But as you pump more and more air out of the chamber, a greater and greater *pressure differential* comes into being.

The pressure differential is the difference in pressure between the inside of the chamber and the surroundings outside. In effect, as you remove the air from the chamber, you lower the pressure inside. The increasing pressure differential makes further pumping more difficult.

Imploding Picture Tubes

The forces involved in a pressure differential — that is, between a very good vacuum and atmospheric pressure — can approach 14.7 pounds per square inch, if we assume zero pressure within the chamber. Although this is, of course, an "ideal" vacuum (we'll find out soon why such vacuums are extremely difficult to produce), the pressure differential doesn't *sound* impressive on paper. But the reality is much different.

Have you ever read the warnings on the care and handling of television picture tubes? What happens when such an *evacuated* tube — one from which air has been pumped — is weakened or breaks? It implodes — explodes inwards — with great force. Crushed by atmospheric pressure, the tube instantly becomes a mass of flying glass and metal bits. These can commit mayhem on anyone nearby.

But can the piston pump really create such a good vacuum? The answer is no — even if you can pump as hard as Hercules. Suppose the pump were powered by some kind of motor or engine, could it work better? The answer here is "yes, but." What happens is that, at some point, as much air re-enters the chamber as is pumped out. Among several causes for this is leakage.

Many of today's smaller laboratories do indeed make use of piston pumps, or specially designed motor-operated pumps known as rotary pumps (see diagram). These and other motor-driven pumps are classed as *mechanical* pumps, having moving parts and powered by some kind of motor, usually electric. What mechanical pumps do, in effect, is "grab" quantities of gas from the chamber and remove them to the outside air.

What limits such pumps? As the pressure is lowered, the oil used to seal the pump from the outside air begins to vaporize. Its molecules take the place of the gas being pumped out. Some pumps use mercury, or special silicone products, as a sealant. These sealants don't vaporize as readily as oil. But even such pumps have a limit beyond which they cannot pump down. Scientists have, however, developed tricks for trapping stray particules of mercury or oil, thus pushing the vacuum frontier slightly farther back.

One of the latest methods developed for going beyond a mechanical pump uses extremely low temperatures made possible by the use of liquid helium. Part of the vacuum chamber is cooled with the ultra-low temperaure (minus 458°F) liquid. Of course, the liquid helium itself is not allowed to flow freely in the vacuum chamber. Instead, it is isolated from the chamber by means of a *heat exchanger*, much as water cools a car engine by circulating through the radiator. The unwanted stray molecules of gas in the chamber "freeze in their tracks" as they hit the cold surface and are held fast. Why? The colder it is, the smaller the *kinetic energy* — energy of motion — of a particle.

Another new technique gives the stray gas molecules an electrical charge. This permits the particles to be

speeded up and "focussed" by means of special electrodes and magnets. A stream of charged gas particles originally collected from the chamber is hurled toward a metal target that is oppositely charged. Thrown with immense force, the particles become trapped deep within the metal target material.

Interestingly enough, this last method also gives scientists a way of measuring very high vacuums. The number of electrically charged particles can be counted by means of a system that measures electric current. The amount of current indicates the number of particles of gas present, and hence the strength of the vacuum.

Stymied by a Measuring Error

For a number of years, progress in vacuums was stymied by a seemingly impenetrable barrier. Try as they might, scientists could not bring pressures lower than a certain limit. Then, in 1947, Wayne B. Nottingham, a physicist at the Massachusetts Institute of Technology, discovered that the trouble really lay in the vacuum *measuring systems* then in use. It seems that scientists actually *had* broken what was then the vacuum barrier long before 1947, but their measuring instruments had simply not kept up with the times.

How does a scientist measure vacuums? He has a choice of devices – about 17 different kinds at last count. Each one is adapted for a given range of low pressures. Some of them make use of the electrical properties of gas at low pressures. Others measure the pressure directly, much like a barometer. As you may recall, a barometer makes use of a column of mercury in a tube – closed at the top and open at the bottom – standing in an open pool of mercury. The pressure exerted on the pool of mercury supports the column of mercury in the tube. The height of the column of mercury indicates the pressure. Sea level atmospheric pressure is equivalent to a column of mercury 760 millimeters high.

Whether or not a vacuum is measured by a barometer-like device, the pressure is usually measured in units equivalent to a millimeter of mercury. This unit, called the *Torr*, is named after Evangelista Torricelli (1608-1647), an Italian physicist and mathematician. Torricelli is credited with having developed the barometer, hence the unit of pressure is named after him. Question: What is standard sea level atmospheric pressure in Torrs?

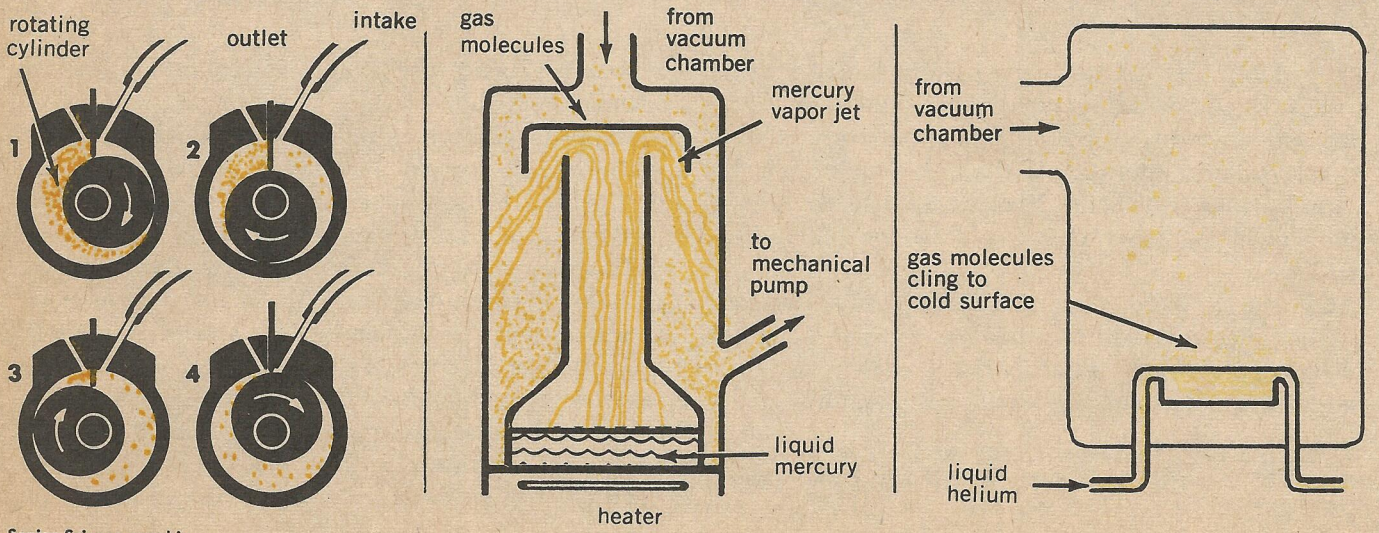
Today's best vacuums approach one billionth of a Torr. What if a scientist were to translate this into the number of gas molecules per cubic centimeter? It turns out that a billionth of a Torr is equivalent to 32,000,000 gas molecules per cubic centimeter. Compare that with the approximately 25,000,000,000,000,000,000 molecules of gas per cubic centimeter at sea level atmospheric pressure! And scientists foresee the day – very soon – when pressures as low as one ten-trillionth of a Torr can be achieved – about 3,200 gas molecues per cubic centimeter.

Why are scientists working hard to achieve such low pressures? At the Missiles and Space Division of General Electric in Valley Forge, Pennsylvania, scientists and engineers have built a chamber that achieves a vacuum of one billionth of a Torr. It is used to simulate the conditions of outer space – including a near-perfect vacuum – without the bother and expense of going there to conduct experiments.

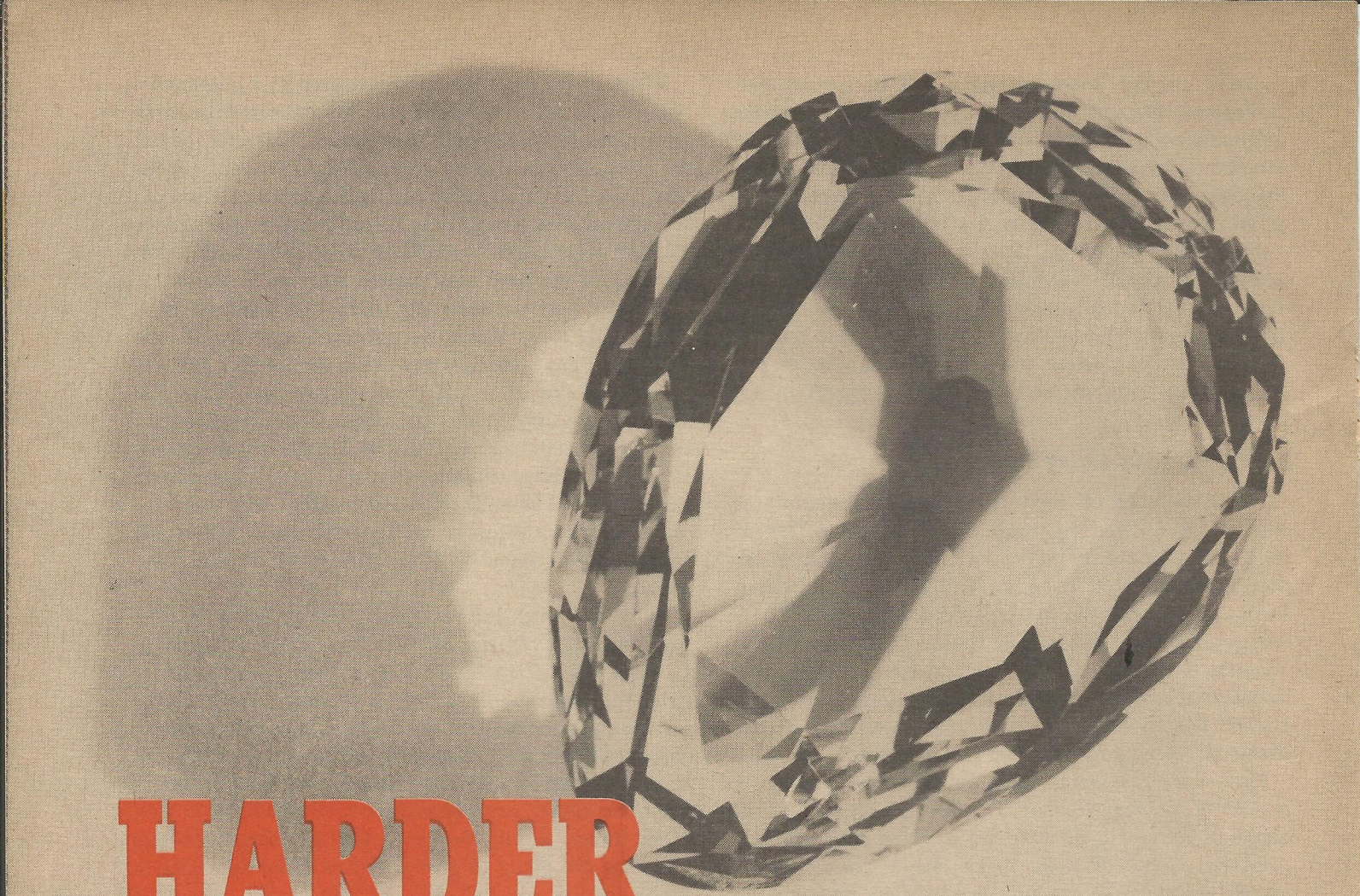
As things stand, the more perfect ultra-ultra-high vacuums are going to give scientists more occasions to reach for the aspirin bottle. At some point, when the pressures get low enough, another problem will crop up. The problem? Without gas pressure to "keep the lid on," the atoms of the material of the vacuum chamber itself will have a chance to become gaseous. That is, the metal will vaporize. So, the problem of the "perfect" vacuum may end up like the problem of the "universal" solvent (which would dissolve everything): What are you going to keep it in?

– Robert L. Wersan

Left: Mechanical pumps remove most air from vacuum system. This one uses rotating eccentric cylinder to sweep air through valve. Center: **Diffusion pump creates high vacuum by removing air molecules with high-speed jet of oil or mercury vapor. Vapor condenses at bottom of pump, is heated and recycled.** Right: **Cryogenic pump uses cold surface to trap stray gas molecules.**



Senior Science graphic



HARDER THAN DIAMONDS?

"ADAMANT" is commonly used to describe something unyielding, such as your father's refusal to part with the car keys. But originally, the word referred to a legendary, unbreakable stone. It comes from the Latin *adamus*, which the Romans used to describe a long-sought substance that would be the ultimate in hardness.

Of course, there is no unbreakable substance. At present, diamond is still the hardest. But our advanced technology demands materials that are as hard, if not harder than diamond, and yet more plentiful. So the diamond is being challenged, and the quest for the adamant continues.

The world's largest diamond is the famous Cullinan, which weighs 530 carats. It is part of Britain's crown jewels. N. W. Ayer & Son, Inc.

Made up entirely of carbon, diamond is a mineral — a substance formed naturally in the earth. It's one of the two natural states in which pure crystalline carbon is found — the other is graphite.

There's a world of difference between the two forms. Graphite is black, dull, and soft. Diamond, when pure, is transparent, bright, and nature's hardest material. Since both substances are composed of atoms of the same element, the difference between them must lie in the way these atoms are arranged. And so it is. For clues to the nature of a substance, we must consider not only the elements of which it is composed, but

also the arrangements of the atoms and the way in which they are linked. This affects many properties, not just hardness.

Both diamond and graphite are *crystals* – that is, their atoms are arranged in orderly rows. But their arrangements are quite different.

Sometime in past geological ages, carbon atoms were squeezed together under enormous pressure and at very high temperature. So tight was the squeeze that electrons of adjacent atoms interlocked, meshing the carbon atoms together in diamond crystals.

Atoms consist of positively charged nuclei surrounded by negatively charged electrons. The number of positive particles (protons) in the nucleus is equalled by the number of orbiting electrons, leaving the atom electrically neutral. The positive charge denotes the *atomic number* of the element.

Carbon, with an atomic number of six, has an inner ring (or shell, as it's sometimes called) of two electrons and an outer ring of four. Because the outer ring of an atom *could* contain eight electrons, carbon's outer ring is incomplete. Therefore, carbon atoms have a tendency to attract electrons from their neighbors. And when the neighboring atoms also have incomplete outer rings, electron sharing takes place. This makes for a chemical linkage called *covalent bonding*.

Working Diamonds

In covalent bonding, atoms "prefer" to share a single electron with each neighbor. Thus, a carbon atom, having four outer electrons, is able to link up with four close neighbors. This is exactly what happens in the formation of diamond crystals: Each carbon atom shares an electron each with four other carbon atoms. The atoms fit around each other in a cubic formation as a result of their mutual attraction.

Such electron sharing provides a very strong bond. Since the diamond crystal build-up is cubic, the result is a tight linkage of atoms in three dimensions.

What about the graphite crystal? Here the story is very different. Graphite atoms are covalently linked together in flat planes – in two dimensions only. The flat crystal arrangement is hexagonal – six-sided. Flat hexagonal plates of graphite are held together by comparatively weak magnetic forces; the layers are not covalently bonded and can easily slide over each other. This is one of the reasons graphite makes a good lubricant.

On the other hand, a diamond is like a single gigantic carbon molecule whose atoms are held together by strong covalent links in every direction. Thus it's extremely hard, and can be cut only in certain specific directions.

Moreover, carbon in a diamond crystal arrangement is the least compressible element: It is almost impossible to squeeze a diamond's carbon atoms any tighter.

So far, we've really been discussing perfect diamond crystal structures. But perfect diamonds, like the legendary adamant, are impossibly rare.

Diamond crystal imperfections may be out-of-place atoms, vacant spaces where atoms should be, irregularities in what should be orderly arrays, and even clusters of foreign atoms. The larger the crystal, the greater the chance of imperfection.

The most perfect diamonds are transparent and colorless. As such (if they're large enough), they're a jeweler's delight. Most diamonds, however, are not used for decoration. Although quite a few diamonds become "girls' best friends" (there were almost two million engagements in the United States last year), ten times more diamonds are used for industrial purposes than as gem stones.

Drilling, boring, cutting, and grinding – these tasks for industrial diamonds increase daily. And this growing need has been the subject of growing national concern for some time. All of our natural diamonds are im-

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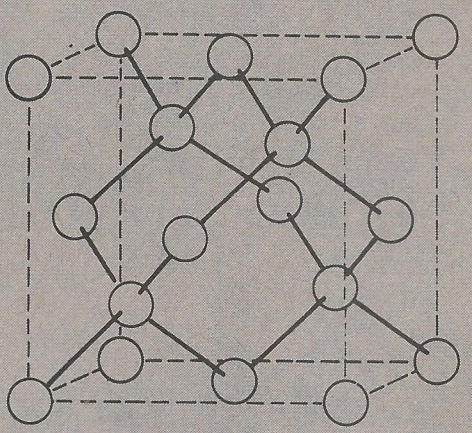
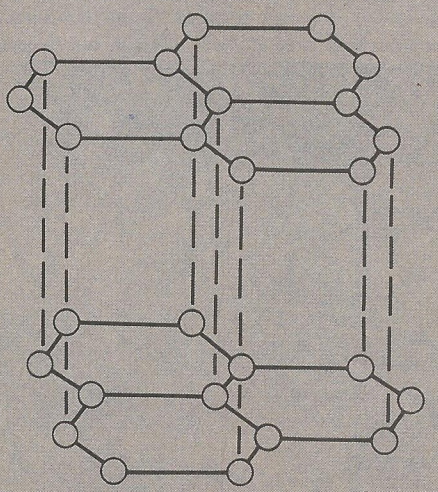




Diamond (above) is the hardest substance because its carbon atoms are held together by strong covalent bonds in every direction. Although the carbon atoms of graphite (below) are tightly bound in layers, the layers are loosely linked.

Senior Science graphic.

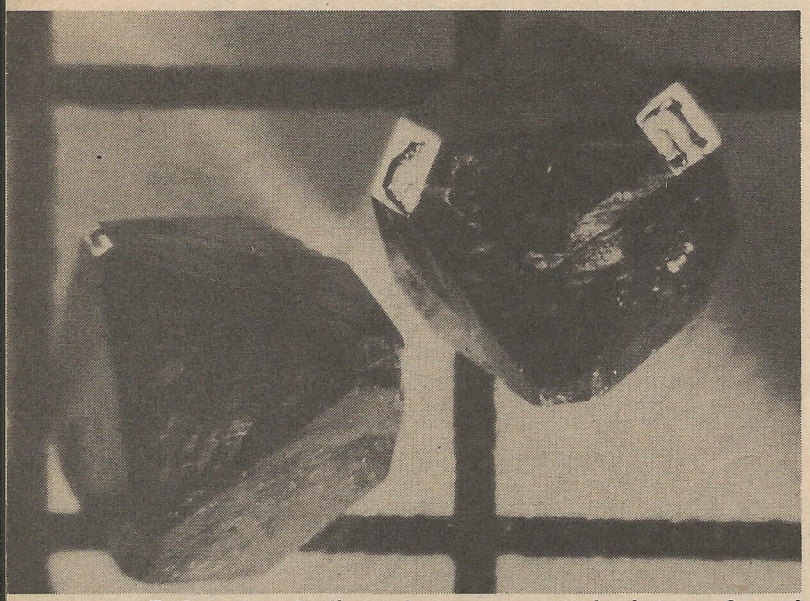
Harder Than Diamonds? *continued*

ported, mostly from Africa. As near-surface deposits are used up, diamond mining becomes more difficult. There's a real danger that the Earth's supply of easy-to-reach natural diamonds may be exhausted in 20 or 30 years.

But scientists are working to counter this threat. Twelve years ago, General Electric researchers introduced man-made diamonds. From a groping start, they are now producing synthetic diamonds for industrial use.

How do you make a diamond? During the last 200 years, both would-be diamond makers and diamond fakers have been hard at work. Because the fakers far outnumbered the would-be makers, the whole effort to make artificial diamonds was tainted for years.

But in 1955, scientists at the General Electric Research and Development Center created a diamond.



Early man-made diamonds were mere specks, but now General Electric scientists are making diamonds weighing two carats.

Drs. Rodney Hanneman, Francis Bundy and Herbert Strong study the structure of a new form of diamond found in meteorites. Photos from General Electric Research and Development Center

Although their creation was a mere speck, it proved the worth of their process.

This process had, in a sense, to duplicate the natural conditions of extreme heat and pressure that bonded carbon atoms into the diamond crystal structure in the first place. And this it did. Under millions of pounds of pressure, at temperatures above 7,000°F, the carbon atoms of graphite rearranged themselves into a diamond crystal structure, identical to that of natural diamond.

Small diamonds are now being made that are generally purer than their natural counterparts. In fact, they're better for grinding, because in grit size (as small as the grains on sandpaper) they are single octahedral (eight-sided) crystals, with many cutting edges.

One discovery usually leads to several others; the making of diamonds is no exception. The same high-pressure and high-temperature techniques were used to make other hard materials. Some of these are now doing jobs that could previously have been done only by diamonds.

Diamonds on the Moon

The hardest of these new materials is a compound of the elements boron and nitrogen, which has been named *borazon*. Although borazon is not quite so hard as diamond, it has a very important quality – a greater resistance to oxidation. At about 1,600°F, diamond will readily combine with oxygen and turn to carbon dioxide – in other words, it will burn. *Borazon* can withstand temperatures that are twice as high.

While continuing experiments with diamond-making techniques, Dr. Francis Bundy and Dr. John Kasper of General Electric created a diamond of unusual atomic structure by harnessing the great force of an explosive shock. The crystal of this diamond is hexagonal (six-sided).

This discovery prompted a search to see if such diamonds also occur in nature. And, while it was decided that no hexagonal diamonds are formed naturally on Earth, there *is* evidence that they've been formed in space!

Recently, hexagonal diamonds have been found in certain types of meteorites. Based on his laboratory experience in shock-producing hexagonal diamonds, Dr. Bundy concluded that the examples in the meteorites were formed directly from graphite by intense impact shock.

Meteorites striking the surface of the moon suffer such intense impact shock. Therefore, it's reasonable to hope that meteorites littering the moon's surface would be rich in hexagonal diamonds. The Apollo moon project should provide the answer to this tantalizing speculation.

Perhaps by the year 2000 we'll be diamond mining on the moon!

— Michael Cusack

All photos by Sam Nocella, University of Pennsylvania

SENIOR SCIENCE TAKES YOU THERE

NEW BOLTON CENTER— Hospital for Very Large Patients

New Bolton Center, Pennsylvania

I SIPPED COFFEE in the NBC cafeteria while waiting for my guide to arrive. Outside, a young man on a palomino horse trotted past the window and dismounted near the parking lot. His clothes—blue button-down shirt, white pants, and brown loafers—looked strangely out of place, as if he were an actor relaxing between scenes of a TV western. But this was no movie set. The young man was a student. I was at New Bolton Center, a clinic and hospital for large animals run by the University of Pennsylvania School of Veterinary Medicine.

New Bolton's hospital and research facilities spread like a small village, fenced amid 720 gently rolling acres near Kennett Square, Pennsylvania. Here, some 32 miles from Penn's main campus in crowded Philadelphia, research scientists, teachers, and veterinary students study and care for sick or injured large animals. Most of the center's "patients" are horses and cattle, but sheep, goats, and virtually all species of farm animals are admitted to the hospital. Perhaps the most unusual visitor to the center was Jewel, a four-ton dancing circus elephant. Jewel injured her right foreleg during a highway accident.

My guide arrived in a few minutes. We walked up the path toward the main hospital and clinic, gingerly avoiding several rain puddles that had formed earlier in the morning. We passed rows of white, neatly kept stables—the "patient wards" of New Bolton—that face the hospital. Then, Dr. Jacques Jenny, a trim, slightly balding surgeon whose bushy eyebrows can't hide the sparkle in his eyes, called to us from the hospital entrance.

Dr. Jenny, who retains a slight accent from his native Switzerland, specializes in repairing chipped and broken bones in horses. "Right now," he said, "we're overrun with horses who've hurt themselves on the race track. But we get all kinds—anything from a colt whose mother has stepped on it to a pony "kicked by a mule."

Dr. Jenny has had particular success repairing long bone fractures. The renowned surgeon repairs a broken leg by carefully drilling holes in the horse's

Continued on next page

Dr. Erkki Rajakoski studies calf to find cause of early embryo death in animals.

bone. The holes are then tapped with screw threads, and a stainless steel pressure plate – the same type used in human patients – is securely screwed over the fracture. The plate holds the broken bone together while healing takes place. "Before," Dr. Jenny said, "if a horse broke its leg, it had to be killed to put it out of its misery. Now it has a better chance."

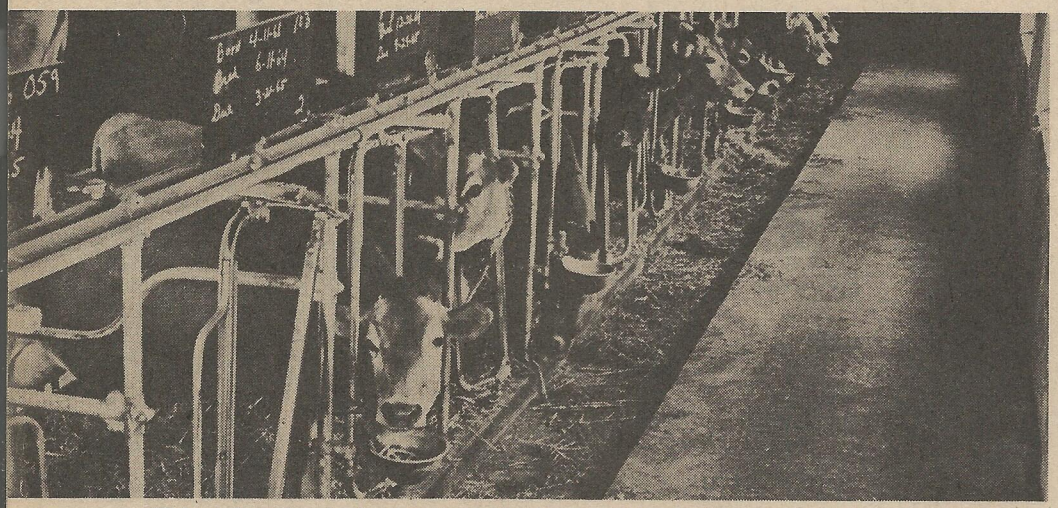
I asked Dr. Jenny what it was like to operate on 1,000 pounds or more of unconscious horse. "If you'll come with me," he said with a touch of pride, "I'll show you the operating room. There's an operation going on right now." We walked down the spotless, yellow-cinder-block-lined corridor through which the horses enter the building from the stables. I became aware of the familiar antiseptic smell of hospitals – touched with a tang of leather and horses. The corridor conveniently divides the examining stations (heart station, where horses are screened for heart disease; X-ray room; and clinic hall) from surgical rooms. We arrived at a white door marked in large black letters:

SPECIAL SURGERY
NO ADMITTANCE

Inside, seven men dressed in green operating gowns, caps, and face masks looked up momentarily from their patient, a sleek chestnut thoroughbred. I wondered how they had gotten the huge animal onto the operating table. The surgical procedure begins, Dr. Jenny told me, in the preparation room, where the patient is clipped, scrubbed, and draped. The horse, still standing, is then strapped to the 3,000-pound movable operating table, which has been tilted to an upright position. Anesthesia is given, and as the horse "goes under," the table is leveled. Then, together with its unconscious burden, it is wheeled on tracks into the surgery room. During surgery, electronic equipment helps the doctors keep close watch on heartbeat, blood pressure, and respiration.

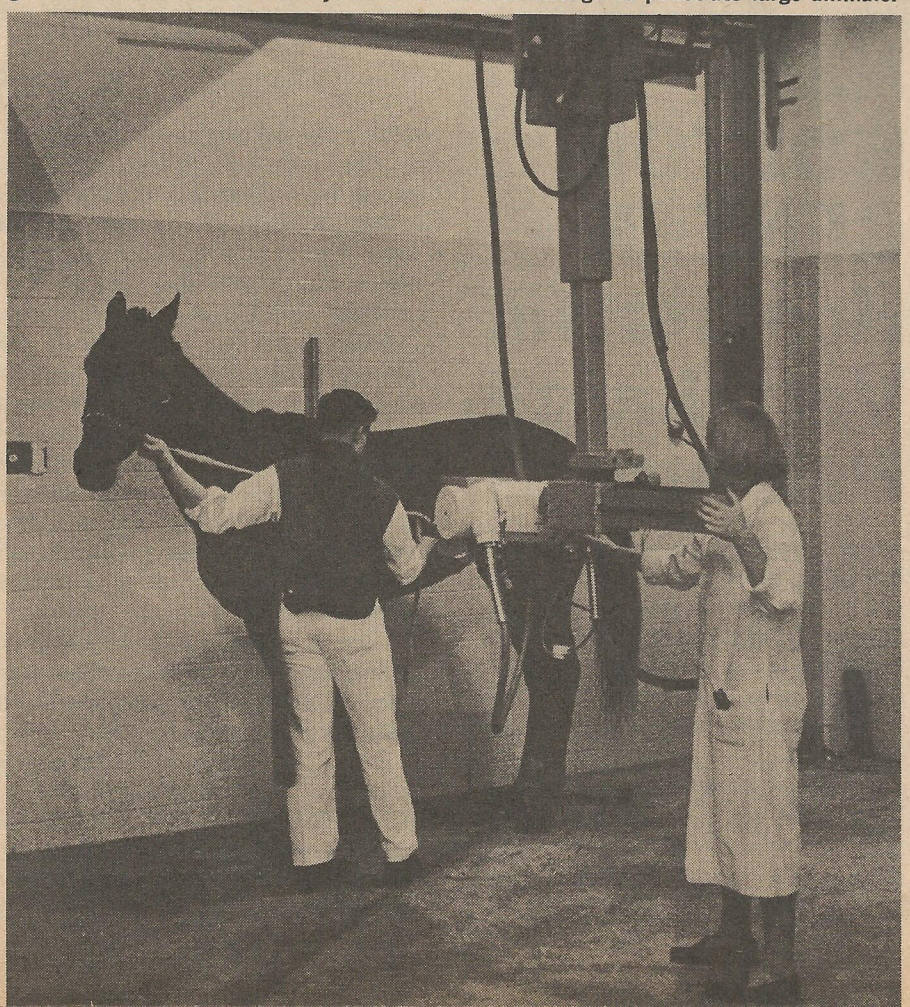
I learned what happens next at first hand. The surgical team had just finished setting the bone on the chestnut's right leg, and were now ready to move the horse. An attendant opened a huge stainless-steel door hinged from the floor of the adjacent recovery room. At the same time, one of the team tilted the operating table until it formed a ramp by aligning with the hinged recovery room door. The surgical team then carefully slid their anesthetized patient down the ramp into the padded recovery room.

We walked into the main corridor to get another look at the horse from the other side of the recovery room. "You know," Dr. Jenny said as he peeked through the observation window at the still-sleeping patient, "when he wakes up, he'll be groggy. His basic instinct will be to get out of there – and in doing so, he might break his leg again. It's too bad we can't tell him to take it easy." He said it as if he had tried to, futilely, many times before.



This unique herd of more than 150 leukemia-prone Jersey cattle are unusual cancer fighting resource. Signs above stalls give breeding, birth information for each cow.

Technician Pat Klunder maneuvers custom-built X-ray apparatus for diagnostic radiogram of horse's shoulder. X rays must be intense enough to penetrate large animals.



Horse undergoes surgery on unique 3,000-pound operating table. Animal is strapped to table while both are vertical, then leveled.

"Some people will think I'm crazy," Dr. Jenny continued, "but I've got an idea – actually it's my pet project – on how to keep them from breaking their legs. It's a swimming pool for horses." Dr. Jenny explained that a horse could be lifted from the operating table in a harness attached to an overhead beam. The harness would have a life raft, which would circle the horse's body. The animal could then be hoisted directly from the operating table to a water tank located nearby. Dr. Jenny's idea is still in the drawing board stage. If it is adopted, it would be one way to tell the horse to "take it easy" and thus give the patient a better chance for recovery.

The treatment of large animals is only one of New Bolton's jobs. The center is also a leader in research on the diseases and reproductive problems of dairy and food animals. Why is this important? For one thing, two thirds of the world's 3.3 billion people go to bed hungry each night. And many experts think that world population will double by the year 2000. The twin problems – too many people and too little food – must be met with an increase in food production. How can production be increased? One way is to learn what interferes with reproduction in food animals.

I spoke to investigators Richard A. McFeely and Erkki J. Rajakoski in New Bolton's section for the study of reproduction. One of their research projects is investigating early embryo death in food animals such as cattle and pigs. In pigs, the rate of such deaths is one-third; in cows, it is somewhat lower. "But," said Dr. McFeely, "since a cow has only one calf, it's an all-or-none proposition." There are still large gaps in our knowledge of the biology of reproduction. Solutions to these puzzles could lead to greater food production – and more food for the world's hungry.

Another important project at New Bolton concerns cancer research. Researchers under the direction of Dr. Robert R. Marshak and Dr. Ray N. Dutcher are seeking the causes of leukemia (a cancer of the blood) in cattle. Bovine, or cow leukemia, is similar to human leukemia. No cure has been found for either deadly disease. If the causes of leukemia in cattle could be found, the cow can be used as a model for studying – and possibly curing – human leukemia.

A herd of more than 150 leukemia-prone Jersey cattle serve as a "research tool" for this long-term project. Experiments conducted to date indicate that a virus may be responsible for the disease. Several questions remain unanswered, however. If bovine leukemia is caused by a virus, does it spread because something in the herd's heredity makes it vulnerable to the disease? If so, is the virus passed from parent to offspring at birth or is it transmitted from animal to animal? Or could the virus be passed to offspring through the mother's milk, as a virus was found to be in mouse leukemia? The special herd remains an exciting biological resource for the clarification of these questions.

Other research subjects at New Bolton range from bovine mastitis, a dairy cattle disease that causes $500 million annual loss in milk production, to diseases in poultry. As I left New Bolton Center, I couldn't help envying that young vet student I had seen earlier riding the palomino. He would receive on-the-job training in a place where research, instruction, and the treatment of large animals are the cornerstones of advancing veterinary science.

— Andre Harvey

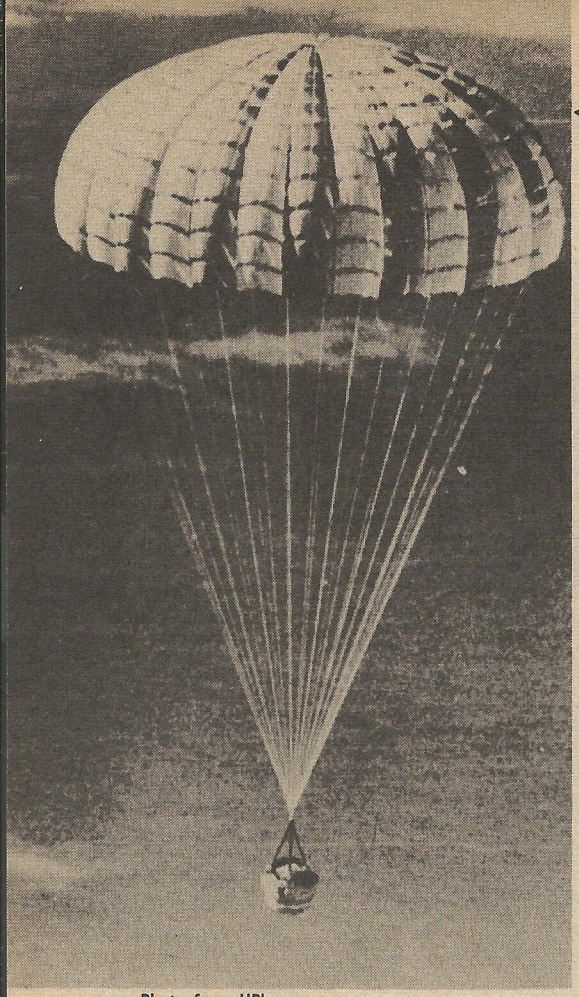


Photo from UPI

◀ **U.S. "Astrobug" satellite with cargo of plants and insects lands 1,000 miles southwest of Honolulu. Scientists report that after 45 hours in space plants aboard Biosatellite 2 sprouted in strange directions due to lack of gravity.**

Ambrose lightship sails off as its successor, a 132-foot tower, takes its place. The new beacon can be seen 21 miles from the New York Harbor.

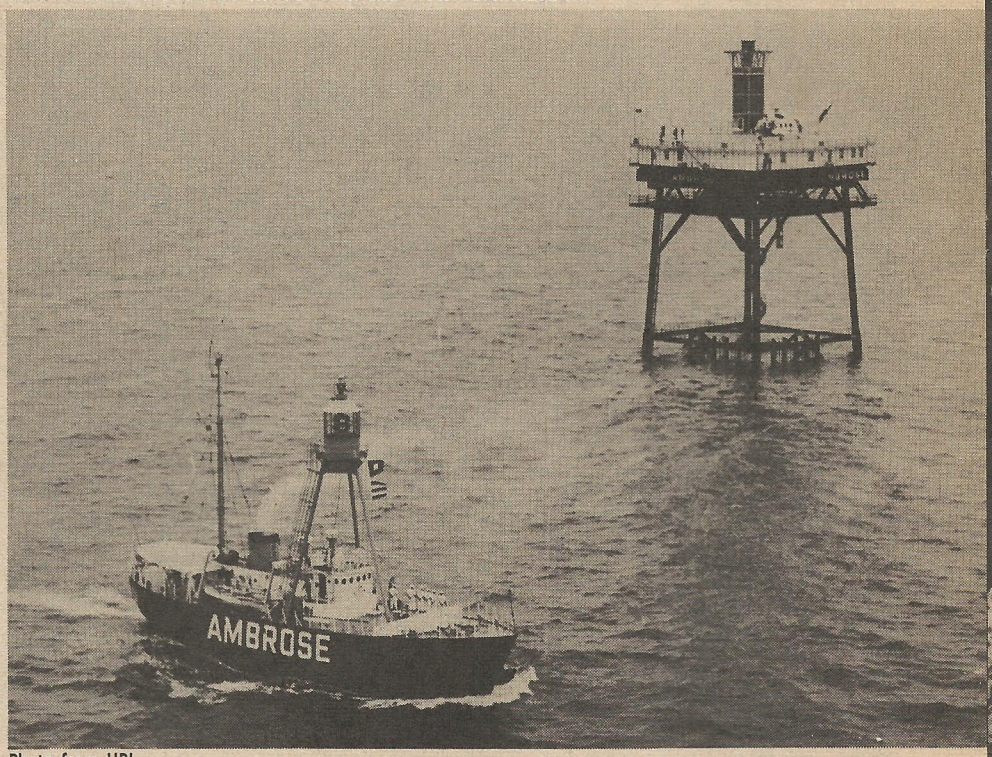


Photo from UPI

SCIENCE IN THE

Pocket-Size TV Antenna

Television aerials will soon be the size of flashlights. In metropolitan areas that are well blanketed with stations, they may even be the size of a 3-inch pen light.

In its research on military communications, the United States Air Force has developed a miniature antenna which works with transistors. Present-day antennas often have an arm spread of eight feet. This is approximately one-quarter of the station's wavelength. The new antennas can get the same kind of picture reception with an arm spread that is only one-fiftieth of the wavelength.

The new antennas will probably sell for $2 or $3, as compared to $5 to $100 for antennas now in use. However, the small antennas will not provide reception in mountainous or remote areas where television reception is difficult.

While TV reception may be improving with new antennas, dangerous radiation was found in some large-screen color TV sets made by the General Electric Company. The hazard was corrected by GE by the installation of a properly shielded tube in more than 100,000 sets that had been sent to dealers, or had already been sold.

Two House of Representative subcommittees are considering a bill to give the U.S. Public Health Service authority to regulate radiation from electronic products.

Skin Color and Vitamin D

Why do different people around the globe have different colors of skin? Scientists have found an answer in vitamin D – the same vitamin that young children take to help them grow strong bones.

Vitamin D is found in cod liver oil as well as in other fish oils and animal liver. But vitamin D is also formed when sunshine hits the inner layer of skin. And, although the vitamin is good for bones, an overdose damages blood vessels. Too much vitamin D can be fatal.

A biochemist at Brandeis University says that dark-skinned peoples developed in tropical, sunny areas. The darker colors helped keep the amount of vitamin D at a safe level. A white-skinned person exposed to tropical sun for six hours can build eight times the normal amount of vitamin D. Such an amount is toxic for an adult. A dark-skinned person, on the other hand, will produce only 5 to 10 per cent of that amount in the same area, says Dr. Farnsworth Loomis.

What determines the amount of sunlight that can safely penetrate the skin to form vitamin D in the body? Two compounds in the outer layer of skin that cause skin coloration: melanin, a substance that actually colors the skin, and keratin, tough skin cells that are found in hair.

In both Europe and Asia, the farther north one travels, the lighter the skins of peoples become. When early, primitive, dark-skinned tribes went north, Dr. Loomis says, their children developed rickets (a crippling bone disease) because inadequate amounts of vitamin D were formed in their skin. Result: Eventually, the tribes were wiped out because their children were not strong

Photo from AP

Photo from Wide World

A radio tower goes up in the Oregon wilds near Hells Canyon Dam. Four-ton tower sections are lowered to workmen by helicopter in the steep terrain.

Op art? No, ... SLOW DOWN. California highway officials put dizzy lines on a dangerous curve between Placerville and Sacramento. The highway ends at top of hill. Many speeding motorists were too fast for the warning signs and the curve was the site of many accidents—until zigzag line was drawn.

NEWS

enough as adults to hunt their own food.

Light-skinned Asiatic peoples can live in hot areas near the equator, says Dr. Loomis, because the outer layer of their skin is heavy with keratin. The dark-skinned Eskimos are an exception to most northern peoples, he adds, because their diet is rich in fish oils.

Gold on Floor of Red Sea

More gold than the forty-niners ever dreamed of finding in the American West has been discovered on the bottom of the Red Sea. Gold, silver, copper, and zinc in one area of the find has been valued at $1.5 billion.

Scientists brought the brilliantly colored ores to the surface from a 7,000-foot deep valley off the continental shelves of both the Sudan and Saudi Arabia. They were obtaining samples in this area to find out why there are hot basins of sea water on the ocean floor. A chain of three hot basins, one of them 8 miles long with sea water temperatures as high as 133 degrees Fahrenheit, has been located in the Red Sea.

The rich ores were found by scientists on an expedition from Woods Hole Oceanographic Institution.

Roaches and Asthma

The cockroach that scuttles behind the refrigerator when you walk into a room is becoming more and more adept at avoiding poison powders or sprays. And as this unlovely creature becomes longer lived, doctors come up with better reasons for its extermination.

Two Washington, D.C., scientists have found that cockroaches cause asthma (a lung disorder that forces a person to gasp for breath). How? They contaminate food with particles of their bodies. Dr. Harry S. Bernton and Dr. Halla Brown report that many persons who eat food contaminated by cockroaches are asthmatic.

The Senses of Animals

In the dark rain forests of Brazil, a boa constrictor locates its prey by the tiny change in temperature that occurs when a small animal appears nearby.

An Amazon fish powers its own radar system with tiny pulses of electricity as it moves through the murky water.

Scientists on a research ship in South America are studying these exotic animals. They want to know what happens during the instant you touch a piece of ice. How soon do you know it is cold? They want to know exactly how a nervous system conveys messages from the sense organs to the brain.

Dr. Theodore Bullock, professor of neuroscience at the University of California, says that heat sensing organs in the boa constrictor can detect minute changes of temperature in its surroundings. And these receptors in the boa are similar to those in the skin of human beings. By studying the output of the electric fish, scientists are hoping to learn something about how the human brain decodes electrical nerve signals.

Scientists are working on these projects aboard the research ship *Alpha Helix* (named for one of the components of protein). The expedition, sponsored by the Scripps Institution of Oceanography, sailed to its present location on the Rio Negro, a tributary of the Amazon River, last spring. The scientists plan to return in February.

These scientists have also learned that the piranha fish, known best for its fierceness, is actually a cowardly creature that prefers crippled prey of its own size or smaller. And they have learned that fresh-water dolphins, once thought silent, actually make high-pitched yelps and barks.

PRODUCED WITH COOPERATION OF THE FUTURE SCIENTISTS OF AMERICA AWARDS PROGRAM OF THE NATIONAL SCIENCE TEACHERS ASSOCIATION SPONSORED BY FORD MOTOR COMPANY

tomorrow's scientists

PROJECT: Color Changes in the Frog

SCHOOL: NOTRE DAME HIGH SCHOOL FOR BOYS, NILES, ILL. TEACHER: **JOHN T. NORRIS**
RESEARCH BY: **GEORGE KOVAC,** WINNER, FORD-FUTURE SCIENTISTS OF AMERICA AWARDS

ALL DAY LONG, the burning rays of the hot summer sun beat down unmercifully on the crowded sands of the beach. It was one of the few really good beach days of the summer, and everyone was making the most of it.

By the end of the day, David T., like some of the other fair-skinned, red-haired people on the beach, knew from the hot, tingling sensation on his back that he was in for an uncomfortable night. He had suffered a severe sunburn within an hour of arriving at the beach.

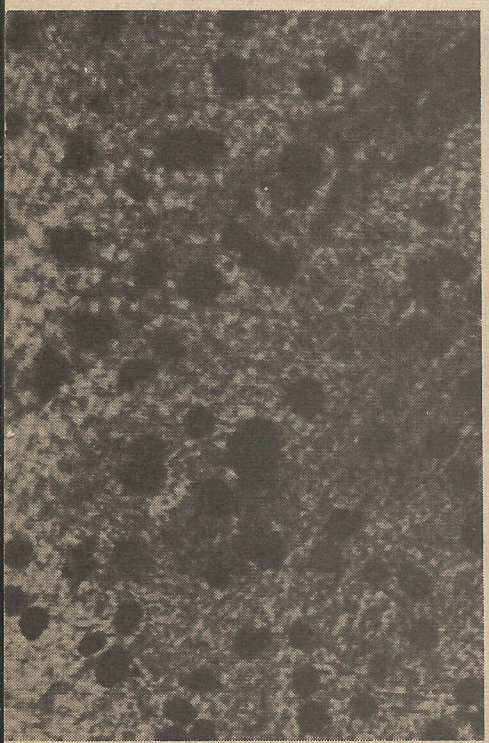
But others, like David's brown-skinned Negro friend, Clark E., or their classmate, Tony G., a heavily-tanned beach lifeguard, would sleep comfortably. They would have no more visible after-effect of being in the sun for hours than a little skin peeling off their noses a few days later.

Every summer, poor David suffers such painful results from over-exposure to the sun's rays because his skin lacks a sufficient concentration of *melanin* granules. This black pigment not only gives coloration to the skin, but also protects it from the sun's ultraviolet rays, which do the tanning *and* the burning.

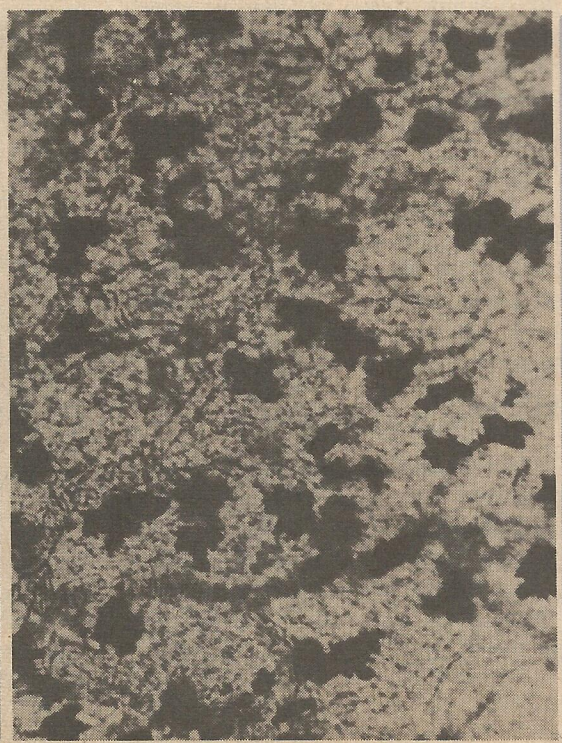
The structure and function of melanin have received considerable attention from research scientists in recent years. An article in the August 4, 1967, issue of *Science* magazine suggested that darkened skin was a necessary adaptation in equatorial regions of the world. It would prevent the over-production of vitamin D, whose synthesis in the skin is triggered by exposure to the sun's ultraviolet rays. Such protection is necessary because too much Vitamin D in the body is poisonous (see news pages). Therefore, inhabitants of more temperate zones, where solar ultraviolet rays are less intense, might have developed lighter skin, which would facilitate vitamin D production.

The function of melanin in other animals may be quite different. In his project, George Kovac investigated the effects of light, heat, and hormones on the color of frogs.

George had learned from library research that *contraction* of specialized cells (called *melanophores*) that con-



A



B

Tomorrow's Scientists

George Kovac took photomicrographs to record his observations of frog pigment cells. A, B, and C show some of the cells that George used for his standard scale for estimating pigmentation. Respectively, they represent stages 1, 3, and 5. Photo D shows pigment cells of frog kept in light-warm environment for 48 hours. Photo E was taken under identical conditions using same frog, after 72 hours. Note decrease in size of pigment cells. Where do D and E fit in George's standard scale?

George Kovac photos

tain melanin results in a *lightening* of the frog's skin. *Expansion* of the melanophores results in a *darkening* of the frog's skin. These changes, some scientists suspected, are related to the release of specific hormones, depending on the nature of the environment.

George divided an equal number of male and female frogs *(Rana pipiens)* into four groups. Each group was placed in a different environment: light-warm, light-cold, dark-warm, or dark-cold. Frogs of the light environments were kept in 2,000-ml beakers containing about 100 ml of water. Light was supplied by a 100-watt, frosted light bulb placed right beside the beakers. Frogs of the dark environment were kept in thick cardboard boxes sealed to keep out any light. A dish of water was placed in these boxes. Warm-environment frogs were kept at normal laboratory temperatures of 25°C-26°C; cold-environment frogs were maintained at 6°-8°C.

George assigned each of the frogs a number according to the following color code values: 1 – green, 2 – olive, 3 – pale brown, 4 – beige, 5 – brown. He then made daily visual observations of the color of the frogs, and made estimates of the concentration of melanin in the frogs' melanophores using photomicrographs. He assigned the degree of melanin concentration a value of from one to five, corresponding roughly to the color values.

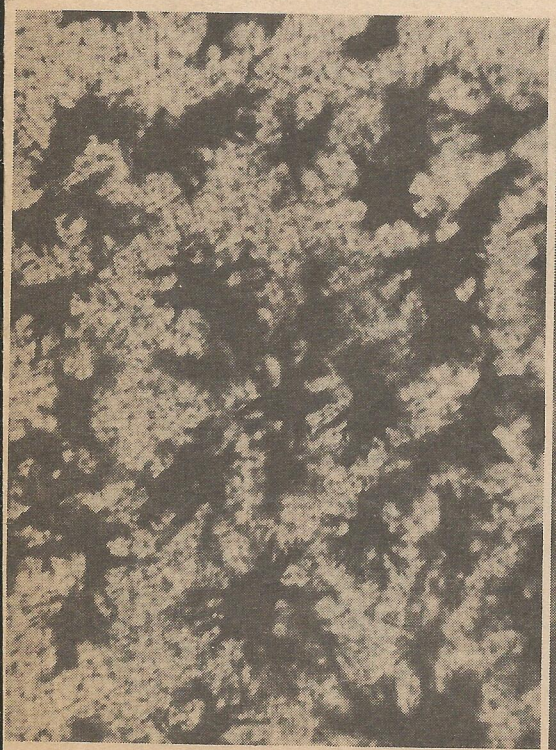
One of George's greatest difficulties was finding a suitable procedure for taking the photomicrographs. He first tried strapping a frog to a soft wood panel, extending the leg, spreading the web of the foot, and pinning it in place. In this manner, the melanophores of the web region could be examined under the microscope without killing the frog. George had to abandon this method, however, because it required an average of 15 minutes to secure each frog, and the web tore easily if the frog jerked its leg. He devised a more efficient method, using two styrofoam blocks hollowed out in the form of a frog, with a special channel for the extended leg. Using this "sandwich" method, George could secure a frog in three to five minutes.

The results of the environmental tests were undramatic, but George was able to note definite trends. All frogs of the dark-cold and light-cold environments darkened after 48 hours. After 72 hours, all frogs in the cold environments were very similar in brown color value of 3.5 to 4. One of the frogs in the light-warm environment showed definite signs of lightening; the other frogs in this group showed little change. Frogs in the dark-warm environment became darker. George concluded that the cold and darkness factors exercised greater control over color change than the warmth and light factors.

Following the environmental tests, George injected two frogs with adrenalin and ACTH, two hormones suggested by the literature. A brown frog showed no change in color after being injected with either hormone. A green frog showed no change after adrenalin injection, but it developed large patches of darkened skin within an hour after ACTH injection. A half-hour later, the frog was fairly uniformly brown in the 3 to 4 color value range.

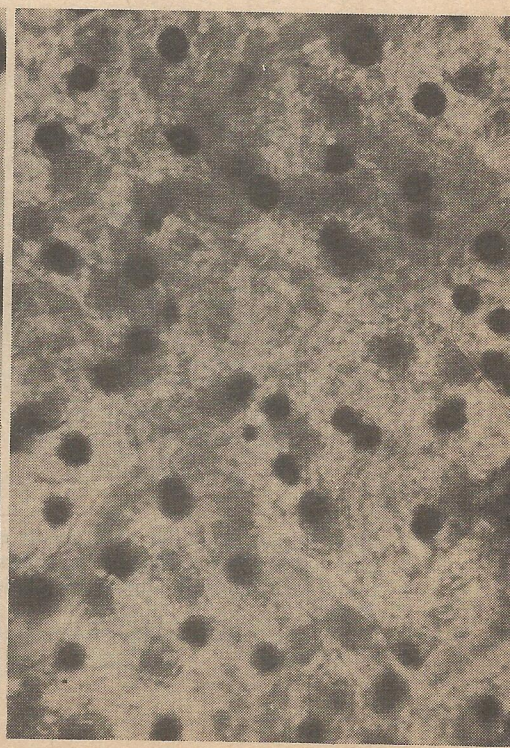
Thus George concluded that in a dark or cold environment, *Rana pipiens* responds by releasing a hormone that stimulates expansion of the melanin pigment in the melanophores. This results in a darkening of the frog's skin. In the absence of the hormone in a light or warm environment, the melanin granules remain contracted, and the frog's green skin pigments dominate.

George noted in summary that in one type of human cancer, melanoma, the cancerous tissue is black because of the rapid production of melanin. Studies of melanin synthesis and movement in the skin may yield important clues about the nature of this type of cancer.



C

D



E

PROJECT POINTERS

Cheese Microorganisms

THE MICROORGANISMS found in cheeses display remarkable variety. These microbes that serve man can make excellent "subjects" for interesting research projects with bacteria and molds.

You may want to start your investigations of cheese microorganisms with a simple microscopic examination of the bacteria that produce yogurt. Buy a container of plain yogurt in a grocery store or supermarket. Dilute 5 cubic centimeters (cc) of the yogurt with distilled water to make 50 cc.

Transfer one drop of the diluted yogurt to a microscope slide on which a drop of methylene blue solution has previously been placed and allowed to dry. Prepare the methylene blue solution by dissolving one gram of the stain (in solid form) in 335 cc of alcohol.

The water in the drop of diluted yogurt will dissolve the methylene blue on the slide. The blue stain will then be absorbed by the nucleus and granules in the cytoplasm of the bacteria. Examine the slide under the high-power objective of a microscope. You will find, principally, *Lactobacillus bulgaricus* (rod-shaped bacteria) and *Streptococcus lactis* (a chain form of bacteria). The blue-stained bacteria will show up nicely against the white background formed by the coagulated milk in the yogurt.

To culture more of the same bacteria, add one-tenth of a container of yogurt to a quart of milk and allow it to stand in a cool dark place (but not in a refrigerator). It will take several days for the lacto-bacteria in the yogurt to multiply and convert the milk into more yogurt.

To study other cheeses, start by dissolving the cheese in distilled water until you get a watery white suspension of the same consistency as the yogurt diluted 1:9 with distilled water. Prepare another slide with one drop of dried methylene blue and add to it one drop of the cheese suspension. Examine the slide under high power.

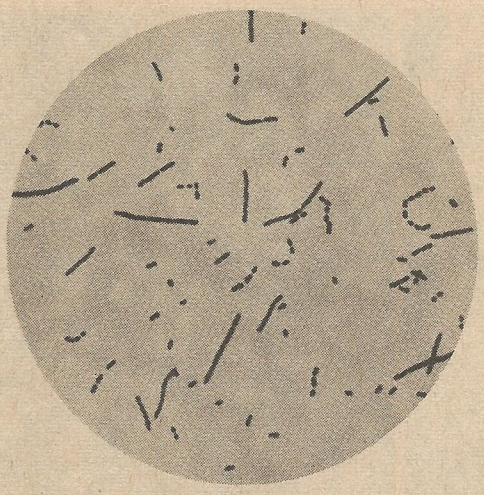
Each of many cheese varieties is produced by a different species of lactobacillus. You may want to prepare photomicrographs of the kinds of bacteria found in different kinds of cheese (see below).

Next you may want to investigate the cheeses that get their flavor from various kinds of penicillin mold. Roquefort, blue cheese, and Gorgonzola are all penicillin mold cheeses.

Remove the blue penicillin mold with a fine needle and place it dry on a microscope slide. No staining is required. The mycelia of the penicillin will be visible under high power. Each kind of cheese mold has a slightly different structure.

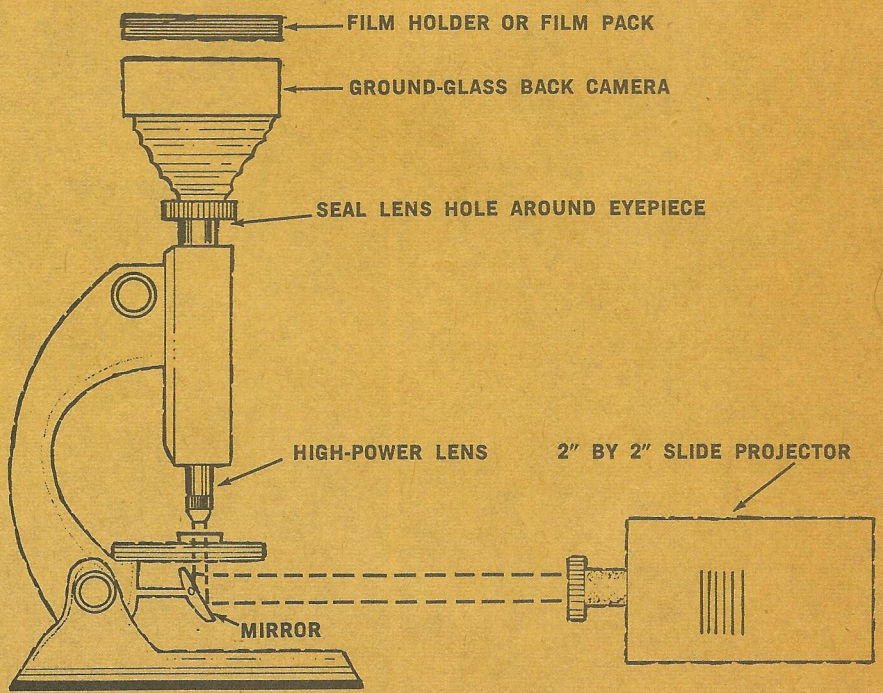
If you want to culture cheese penicillin, simply use other plain cheeses as a culture medium. Jab a thick needle into the penicillin in a cheese. Then jab the needle carrying the penicillin into plain cheese such as cream cheese, Neufchatel, farmer cheese, or white cheddar. Leave it in a cool dark place. Record the temperature.

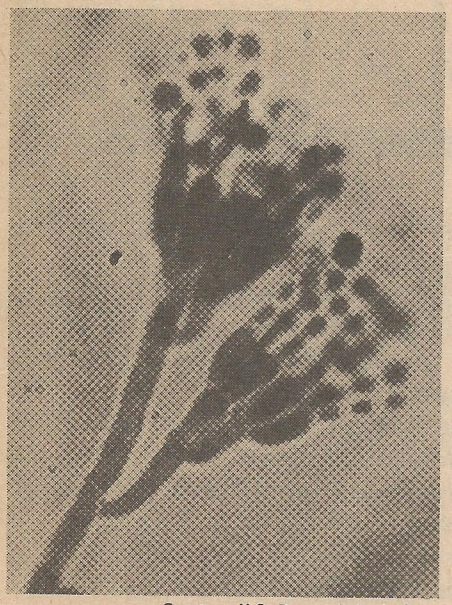
Keep a photographic record of the cheese in which you are culturing peni-



This photomicrograph of a smear of yogurt shows both Lactobacillus bulgaricus (rods) and Streptococcus lactis (chain-like forms).

Courtesy General Biological Supply House, Inc.





Courtesy U.S. Dept. of Agriculture

Photomicrograph at 630× magnification shows Penicillium notatum, the mold from which the antibiotic drug penicillin comes.

cillin. One question you can try to answer is this: At what temperatures will the penicillin cheese cultures grow most rapidly?

If you do not have a camera equipped to take photomicrographs, you can easily make your own. Obtain an old camera that has a ground-glass back. No lens is necessary; the microscope eyepiece acts as the camera lens. You will need a film-pack holder or sheet-film holder that fits the camera.

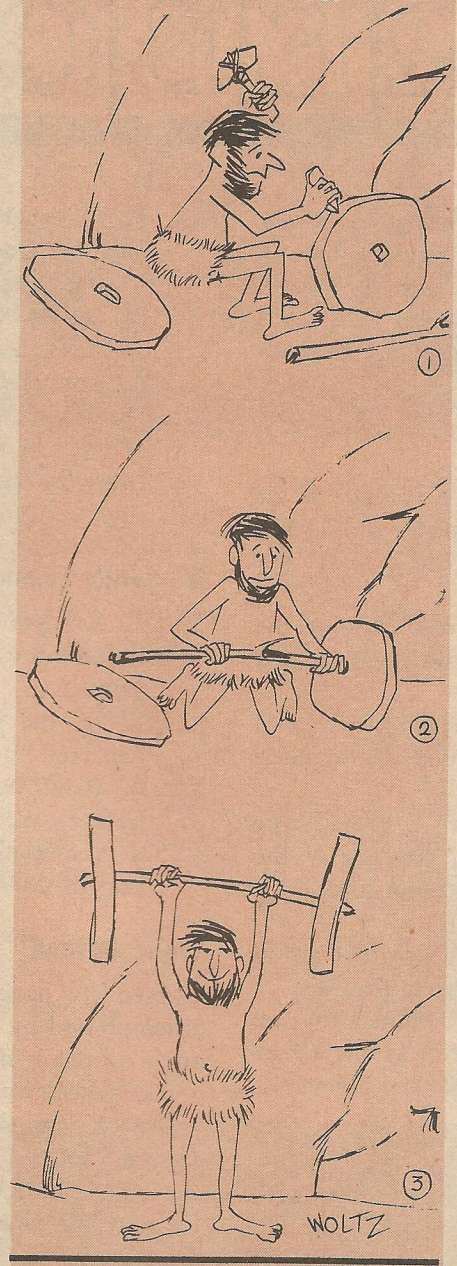
Slip the lens opening of the camera over the microscope eyepiece (see drawing). Seal the space between lens and camera with black plastic tape. If the camera bellows leaks light, patch the light leaks with the same kind of tape.

As a light source, use a small 2-inch-by-2-inch slide projector aimed at the microscope mirror. With the light turned on, focus the bacteria on the ground glass. Take several different exposures by turning the light on for one second, two seconds, three seconds, and so on.

Develop the film in the usual way. If your negatives are under-exposed, allow additional time for exposure. If your negatives are over-exposed reduce the exposure time.

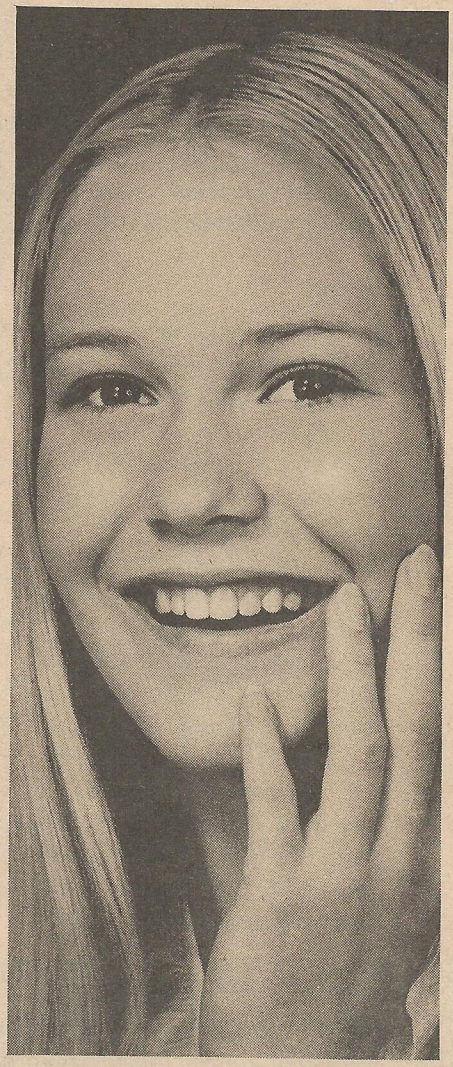
— ALEXANDER JOSEPH

SCI-FUN



"I'm afraid you're too late."

Look! Clearer skin from a soap



with new medicated Jergens Clear Complexion Bar

It actually helps clear your complexion simply by washing your face!

Jergens' rich, specially medicated lather washes away excess oiliness. Fights blemishes. Fights the bacteria that make them grow.

Continued use helps keep blemishes from coming back. Yet this clear, transparent soap never dries or irritates your sensitive skin.

Try it.

FROM THE JERGENS SKIN CARE LABORATORIES

SCOREBOARD

How well have you read your *Senior Science*? Answers to questions with no asterisks may be gleaned directly from the articles. Answers to questions with an asterisk (*) require fusing the facts in the articles with those learned in the classroom or from your reading. Answers are in the SCOREKEEPER on page 31.

I. Vacuums

_____1. The pressure at the base of a column of air reaching to the edge of the atmosphere and having a 2-square-inch cross-section is 14.7 pounds per square inch.

_____2. Even if we could make a perfect vacuum, the container could not withstand the pressure and would collapse.

_____3. Using a piston-type vacuum pump, we could achieve a perfect vacuum, provided we operated it for a long enough period of time.

_____4. Standard atmospheric pressure is taken to be that which is equivalent to the pressure at the base of a column of mercury 760 mm high.

_____5. The Torr is a unit of length.

_____*6. All points on the Earth's surface that are at sea level have the same atmospheric pressure.

_____*7. The best vacuums presently attained are produced by "ion" pumps operating at as low a temperature as possible.

II. Harder Than Diamonds?

_____1. Man-made substances have been produced with a hardness greater than that of diamond.

_____2. Graphite, carbon, and diamond are chemically identical.

_____3. The bonding of one carbon atom to another involves the transfer of the four carbon atoms of one atom to the outer ring of another.

_____4. In graphite, the bonding of one carbon atom to its neighbors is largely in two dimensions.

_____5. Synthetic diamonds are not so hard as natural diamonds.

_____*6. Of all known transparent substances, the diamond is the one in which the velocity of light is slowest.

III. Microbes at Work

_____1. Yeasts and molds are classified as fungi. The main difference between the two is that molds are multicellular.

_____2. Yeasts are responsible for the souring of wine.

_____3. The energy for the life processes of yeasts is obtained from the process of fermentation.

_____4. Unlike most European wines, American wines are pasteurized before fermentation.

_____5. Yeasts do not reproduce sexually. They reproduce only by asexual budding.

_____*6. The heat energy liberated from the burning of sugar in air is greater than the energy liberated from the fermentation of the same amount of sugar.

IV. Senior Science Takes You There

_____1. A horse with a broken leg is generally shot because the broken leg can never be made to heal properly.

_____2. By the year 2000, the world's population is expected to be more than six billion people.

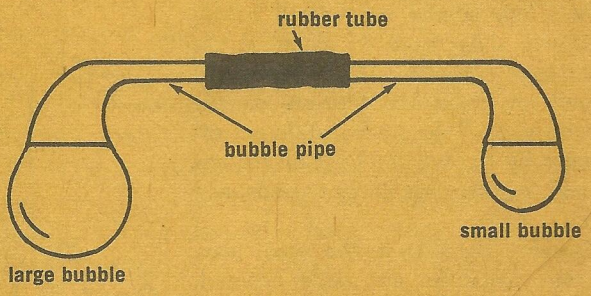
_____3. It has been shown that leukemia in cows can be transmitted to humans.

_____4. Experiments have shown that leukemia in mice may be transmitted by means of a virus.

Going Beyond

Scientists have found that budding of yeasts is accomplished by the reduction of the cell-wall proteins and a softening of the wall, whereupon internal pressure within the cell causes the bud to form.

Here is a model that will take a little thinking to explain. Get two bubble pipes and blow a bubble in each. One bubble should be small, the other large. Connect the ends of the bubble pipe by means of a short length of rubber hose as shown.



1. What do you think will happen? Will the large bubble become smaller or larger, or will the situation remain unchanged? The best thing to do is to try it out for yourself. (Hint: the result is usually surprising.)

2. Why does this experiment work opposite to the principle of the budding yeast?

ANSWERS TO BRAIN TEASERS
(see page 29)

Art Appreciation

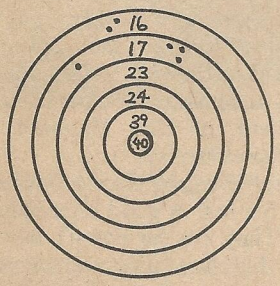
With the second frame, the price was reduced $2.00. The reduction represents half the charge for the first frame, which must therefore have been $4.00. Thus, the charge for the painting alone would have been $8.00.

Squared Away

Eleven squares are formed by the lines in the figure.

Target Teaser

Four darts in the "17" ring and two darts in the "16" ring represent a total score of 100.

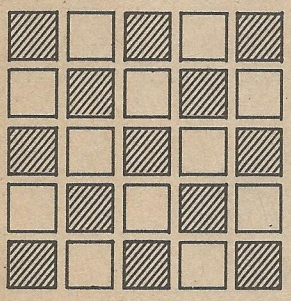


To Tell The Truth

Everyone in the town will say that he is a truthteller. Truthtellers will be answering truthfully. Liars will be lying, as expected. Accordingly, Gritty must be a liar, since he did not truthfully report the first man's response.

Editor's Choice

Let the 5 x 5 square formation of foxholes be represented by the checkered figure below.



According to the scout leader's order, every girl in a foxhole represented by a black square must move to a foxhole represented by a white square. This can be seen to be impossible, because there are 13 black squares and only 12 white ones. Thus, the order cannot be carried out.

DISCussions

By ROY HEMMING with Robin McBride, Ed Coach, Buzz Royden

CLASSICAL — album of the week

Charles Ives: Holidays (George Washington's Birthday, Decoration Day, July 4th, Thanksgiving)—Donald Johanos, Dallas Symphony, Southern Methodist University Choir [*Vox Turnabout TV-34146S*]. Mark this not only as one of the outstanding budget recordings of the year, but also as one of the best performances of any of Ives' work since belated interest in his music began to take wing a few years ago. New Englander Ives (1874-1954) wrote music that mixes melody with dissonance, seriousness with wild humor, and popular tunes with some of the most challenging harmonies of the century. It is not "easy" music on first hearing, but repeated hearings are convincing many that Ives may be the most important U. S. composer to date. Three parts of this "Holidays" symphony have previously been recorded by Leonard Bernstein as "fillers" on other Ives LPs (for Columbia). As good as Bernstein's versions are, Johanos' are better. Johanos brings a clarity

Johanos

Ozawa

of instrumental detail to some passages where Bernstein merely piles sound on sound—yet Johanos never loses dramatic thrust or intensity in the process. He also lets Ives' raucous humor spring up more naturally from the sonic mix. In short, a great debut LP from Johanos and Dallas! (R.H.)

Honegger: Joan of Arc at the Stake—Vera Zorina, Seiji Ozawa, London Symphony, Chorus and Soloists [*Columbia 3221-004*]. This extraordinary oratorio on the martyrdom of Joan of Arc (which Swiss composer Arthur Honegger and French poet Paul Claudel composed in 1938) remains one of the most shining works of its kind in 20th-century music. It has yet to receive a completely satisfactory recording. An earlier (1953) Columbia set, also with Zorina, was marred by matter-of-fact conducting by Eugene Ormandy. Young Ozawa is much better, but he still does not give the work quite the contrasts in excitement and tenderness, sardonic bite and emotional expressiveness that Charles Munch has given the work in concert performances. Yet the qualities of Ozawa's new version are ample indeed—and there are few actresses who can equal Zorina's eloquence in this role. The new version is the first in English, and the translation is a fine one. So is Columbia's stereo engineering. (R.H.)

JAZZ — album of the week

Johnny Smith [*Verve V-8692*]. There is a strong argument for saying that Johnny Smith is *the* jazz guitarist, and this album is proof of the pudding. In the early 1950's Smith gained wide popularity in the bop movement. Then he "retired" to Colorado Springs to teach in his own studio there. Obviously Johnny has been learning too. From a contrapuntal "Michelle" to an unaccompanied "Golden Earrings," he's at his very best throughout the album. (R.M.)

Baby, But Grand!—Horst Jankowski [*Mercury SR61106*]. Among present-day pop pianists, Stuttgart's Jankowski continues to turn out some of the brightest, bounciest, least icky arrangements on either side of the Atlantic. With orchestral and choral backing, he's in super form throughout this latest set. (B.R.)

POPULAR — album of the week

Bee Gee's 1st [*Atco SD33-233*]. Some critics have been saying that this group sounds like The Beatles. Quite true, but it's not to their discredit. In this album (produced in Australia) they display a neat array of many-flavored, self-penned tunes, and terrific performances. Of the 14 tunes (yes—count 'em, 14!), the standouts are "New York Mining Disaster 1941," "Cucumber Castle," and "Holiday." (R.M.)

The Electric Prunes—Underground [*Reprise RS6262*]. On their first album, the Prunes introduced some electronic and reverb effects previously unheard of in pop music. Well, other groups have gone that route since, and on this new album the Prunes may disappoint those looking for even wilder sounds. Still, this is a top pop album and belongs in the forefront of what's really grooving. The tunes are fine—most of them carry a message—and there are many, many ears just waiting for such messages. (R.M.)

Evolution—The Hollies [*Epic BN26315*]. A terrific 10-track selection by the group that's been tearing up the British and States-side charts for some time. On this, their first Epic album, their approaches are fresh and exciting. Best grooves: their hit "Carrie-Ann" and a topnotch tune, "Stop Right There." More gassy licks from the British Isles. (R.M.)

Living Brass—That's Life [*RCA Camden CAS2143*]. Mexican-style brass and percussion furnish the name of the game (Tijuana) these days, and the Living Brass is very much with it—and at budget-label prices, too. They produce a stimulating hybrid sound that can best be described as mariachi-cum-rock. It's full of fun and fire, and guaranteed to keep you up all night. Besides the title tune, highlights include "Cry," "Riders in the Sky," and "Mariachi Blues." (E.C.)

SPORTS

witness for the defense

MENTION the name of Lance Alworth or Dave Parks to a football fan, and his face will light up like a Christmas tree. It figures. All the great pass receivers are pin-up boys whose names are always headlines.

Mention a name like Kent McCloughan, however, and the average fan will scratch his head and mumble, "Who he?" This also figures. When an ace receiver goes out for a pass, who watches the man who covers him? Nobody – except maybe the coaches, scouts, and the player's relatives.

Poor defensive backs. They are the unsung heroes of football. Where would a team be without a swifty or three to hound the opponents' catch-and-run artists?

That's what Kent McCloughan is – a defensive bloodhound. And there's none better at the trade. Ask a great receiver like Alworth about him, and he'll probably shake his head and groan, "That sonuvagun is like the FBI. You can't fake him, dodge him, or lose him. He sticks to you like five o'clock shadow."

McCloughan (pronounced Mick-CLEW-an) is one of the kingpins of the great Oakland Raiders' defense. At six-feet one-inch and 185 pounds, he has nice size for a corner back. And he also has the brains, reflexes, and, most important, the blazing speed.

It usually takes three or four years for a corner back to master his trade. In Kent's case, it took just one. Like most star defensive backs, Kent started out as a runner. As a halfback at Nebraska in 1964, he led the Big Eight in scoring. But Kent had no illusions about his ball-toting ability.

"I never really had any great seasons at Nebraska," he says. "I was just fairly big and had some speed." After his senior year, he was drafted No. 3 by Washington in the National League and No. 11 by Houston in the American League.

Operating behind the scenes, however, were the Raiders. They had been scouting Kent for years and were convinced that he had the makings of a great defensive back. Unable to get him in the draft, they worked out a deal with Houston, and that's how Kent wound up in Oakland.

The former Cornhusker showed such speed and reflexes that he moved right into a starting position. After a good rookie year in 1965, he made the All-League team last season.

In his shoulder pads and silver-and-black helmet, Kent looks every inch the pro football warrior. Off the field, he's strictly Jack Armstrong the All-American boy. With his blue eyes, short brown hair, freshly scrubbed good looks, and boyish smile, he's every girl's idea of what the boy next door should look like.

Kent grew up in Broken Bow, Neb. – population 7,500 – and went on to fame in high school sports. He averaged 20 points a game in basketball, made all-state in football, and set a state track record for the 220-yard dash. But football was his No. 1 sport. "In Broken Bow, you're expected to play football as soon as you learn to walk," he explains.

"My first big problem as a pro," he says, "was learning to run backwards. College teams usually play zone defense. That means a defensive back watches the quarterback and takes any receiver coming into his zone. He backs up by moving sideways. The pros play man-to-man defense. You take a definite receiver and stick with him wherever he goes. As he comes off the line of scrimmage, you must run backward and stay in this back-up position until the man makes a break.

"All the pro receivers have good or great speed and all sorts of tricky moves. The defensive backs are always studying films of them. Before a game, I'll study the movies of our opponents' two or three previous games. I'll run them over and over, looking for my man's moves – how he tries to beat the defensive backs."

Who are the toughest flankers in the American League?

"All of them are tough – all of them can give you a nightmare on any given Sunday, especially if their quarterback is 'on' or if your line isn't putting pressure on the thrower. I particularly hate to see Lance Alworth, Otis Taylor, Gino Cappelletti, or Don Maynard on the other side of the line.

"Lance is tremendously fast and goes up for the ball as good as anyone in the game. They say he doesn't have many moves, but he's always showing me a few new ones. He never seems to do the same thing twice.

"Taylor is tall, with real good speed, good moves, and great hands. What makes him even tougher to cover is that he has a great quarterback (Len Dawson) throwing to him.

"Don Maynard is tough for the same reason. He has deceiving speed, good moves, and Joe Namath pitching to him. They tell me he drops a lot of passes. But he seems to hold on to everything when I'm playing him."

All of this happens to Kent every Sunday. But he isn't exactly helpless. He can run with all of these stars, and he can make them see a few different kinds of stars whenever they do dare to grab a football under his nose.

– HERMAN L. MASIN, *Sports Editor*

For Further Reading

Microbes at Work

Champagnot, Alfred, "Protein from Petroleum," *Scientific American,* October 1965.

Rose, Anthony, "Yeasts," *Scientific American,* February 1960.

Search for the Perfect Vacuum

Roberts, Richard W., and St. Pierre, Leon E., "Ultrahigh Vacuum," *Science,* Vol. 147, No. 3665, March 26, 1965, pp. 1529-1542.

Roberts, R. W., "Ultrahigh Vacuum," *Science Journal,* December 1965, pp. 32-39.

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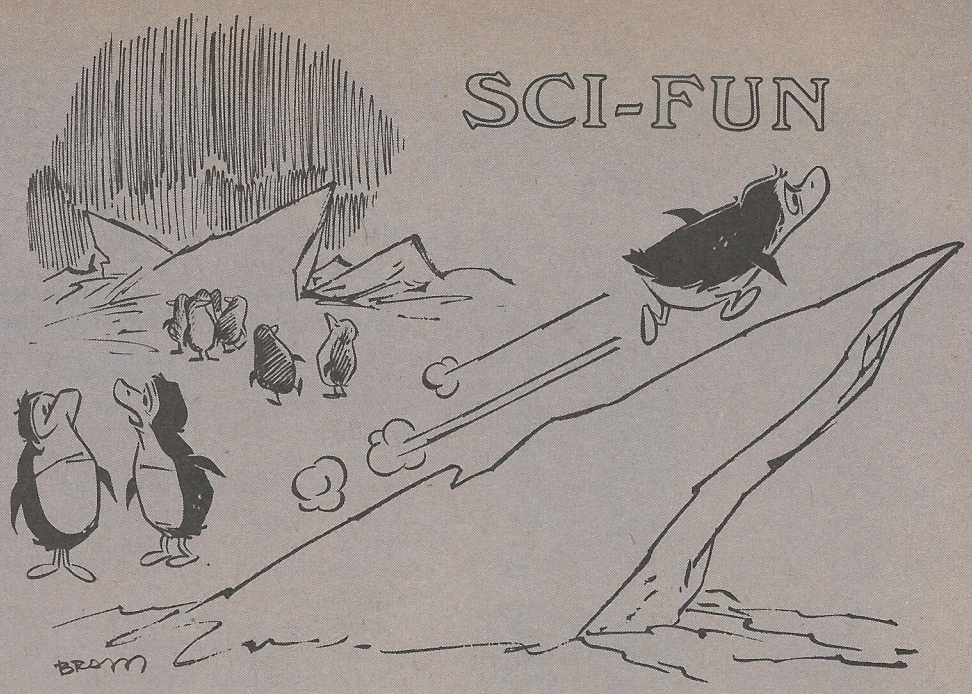

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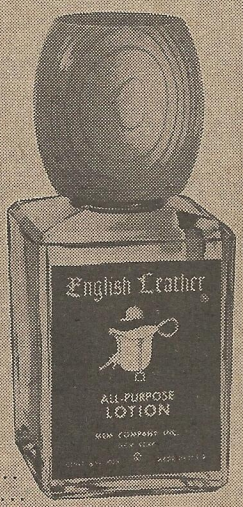

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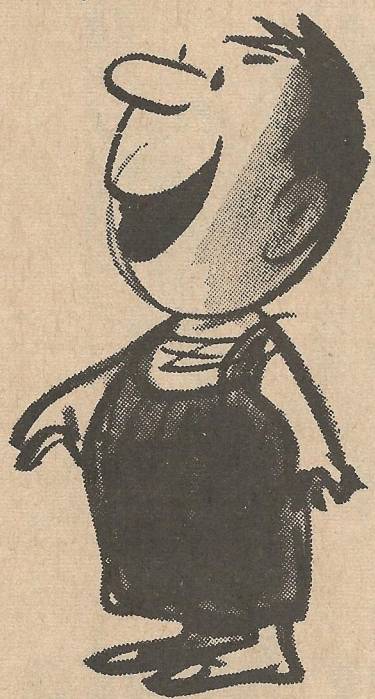
Cartoon by Whitney Darrow, Jr.



Be a buddy!

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FOLLOWING THE FILMS

THE FLIM-FLAM MAN
(20th Century-Fox)

"Greed is my business," Mordecai (George C. Scott) tells Curley (Michael Sarrazin), and he means the greed of those who hope to get something for nothing. Mordecai is a "con man," a trickster who takes advantage of people who think they are going to take advantage of him. His specialties are "flim-flams" – confidence tricks designed to swindle would-be swindlers – for, as Mordecai knows, "You can't cheat an honest man."

When Curley joins forces with Mordecai, both are rootless drifters. Curley is A.W.O.L. from the U.S. Army, having punched a bullying sergeant. Mordecai has never had a home or an identity. Keeping just one jump ahead of the police, he shifts identities as he changes towns.

At first, Mordecai's Huck Finn existence seems like fun to Curley. But then the old con man breaks his own rule about not cheating the honest, by stealing a good Samaritan's car. Curley sees Mordecai for the shifty wastrel he really is, but he feels he owes him a debt of friendship. He gets an unexpected chance to repay it with the biggest flim-flam of all.

This charming comedy has a lot to say about the loneliness of dishonesty, and it makes its point without preaching. The performances are all first-rate, especially those of George C. Scott and newcomer Michael Sarrazin. Adapted from Guy Owen's novel, *The Ballad of the Flim-Flam Man*, the film is sparked with easy-going humor which builds to a hilarious height as Mordecai inadvertently demolishes a town as he tries to escape from it.

George C. Scott is a crafty con man who pulls "flim-flams" in a charming comedy.

TARZAN AND THE GREAT RIVER
(Paramount)

Don't get us wrong – we're Tarzan fans. In our opinion, there's no greater swinger than the Ape Man. But Mike Henry doesn't seem up to the strenuous job of playing Tarzan. Swimming leaves him winded, and he walks as if his feet hurt. He needs all the help he can get from his pet lion and his old pal, Cheetah the Chimp.

In this film, Tarzan is on the Amazon River in Brazil. His mission: track down the evil Barcuna (Rafe Johnson), a tribal chief whose followers are terrorizing more peaceful Amazon Indians.

As Tarzan trails Barcuna upriver, he has to fight off hippos and lions and tigers. None of these animals lives in Brazil, as everyone but the maker of this film seems to know.

— Margaret Ronan

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brainteasers

ANSWERS ON PAGE 25

Do you have a favorite brain teaser? Send it to Senior Science, 50 West 44th St., New York, New York 10036. We will pay five dollars for each one published. Include the name of your school, home address, grade, and age. In case of duplicate submissions, choice will be made on the basis of presentation and clarity.

Art Appreciation

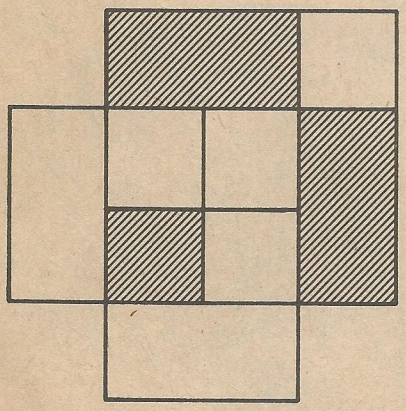
"I'll tell you what I'm going to do," drawled the art dealer. "For only $12.00 that beautiful painting and the captivating frame it's in are all yours. Or," he continued, "I'll put the painting in this other frame, which is half the value of the first one, and you pay only $10.00."

How much should the art dealer charge for the unframed painting?

Chris Vincent
Dorner Jr. H. S.
Richmond, Cal.

Squared Away

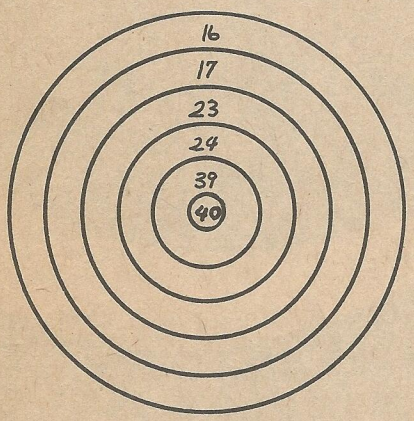
How many squares are formed by the lines in the figure below?



Alan W. Wilson
Wareham Jr. H. S.
Wareham, Mass.

Target Teaser

Consider the dart board depicted below.



How could a score of exactly 100 points be obtained?

Mitchell Schwartz
Central High School
Philadelphia, Pa.

To Tell The Truth

Through the ages brainteasers involving "truthtellers and liars" have appeared in many versions. Here's one that is as basic as any.

A town is inhabited by two groups of natives – one group always tells the truth, the other group always lies. A stranger arrived in town and asked a native if he was a truthteller or a liar. The stranger did not hear the native's answer. Two other natives, Nitty and Gritty, who overheard the conversation were asked what the first native had said.

Nitty replied, "He said that he's a truthteller."

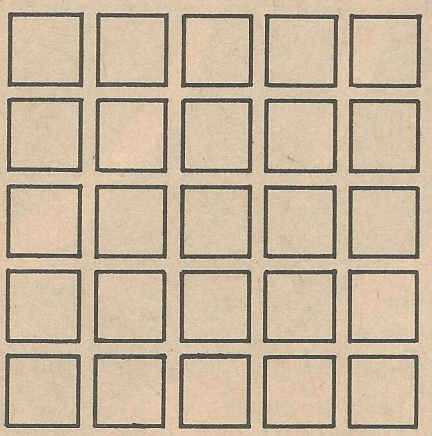
Gritty responded, "He said that he's a liar."

Is Gritty a truthteller or a liar?

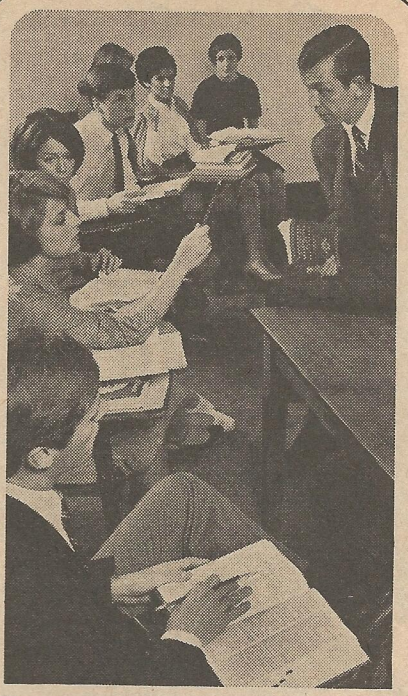
Billy Begert
Grandby Jr. Sr. H.S.
Grandy, Mass.

Editor's Choice

A platoon of 25 girl scouts is entrenched in 25 individual foxholes arranged in a square formation of five rows with five foxholes in each row.



The scout leader orders that each girl is to move to a different foxhole by moving either to the foxhole in front of her, in back of her, or to the right or left of her. Can this order be obeyed? How do you know?



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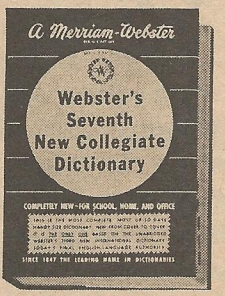

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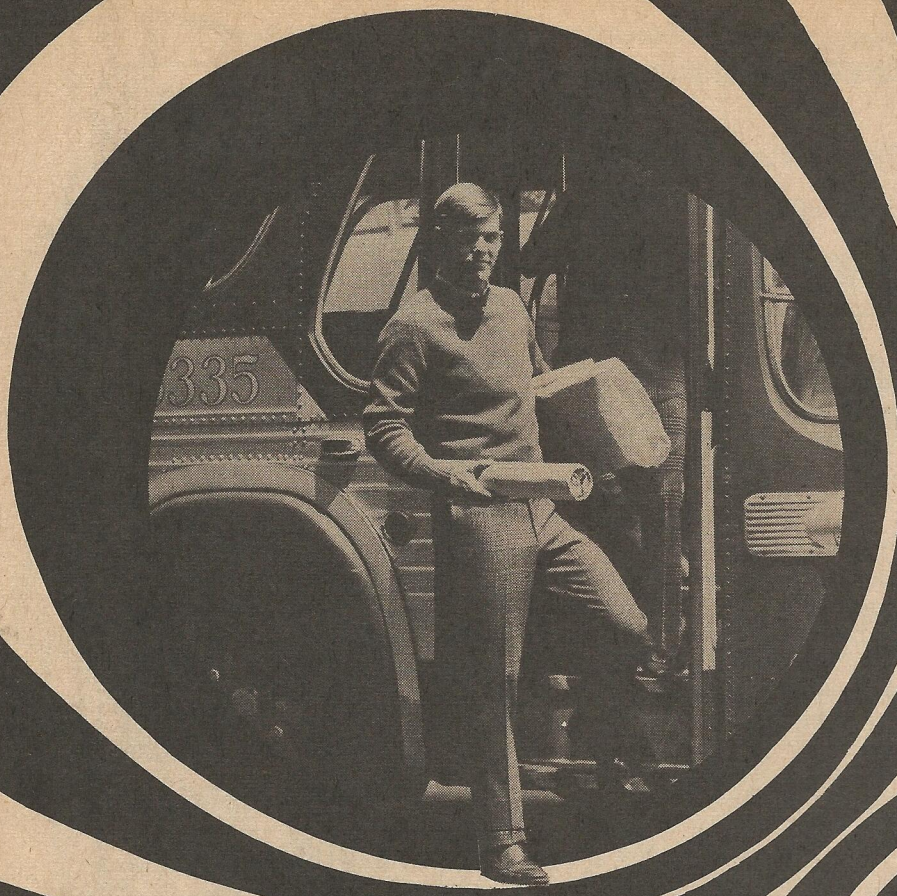

THE SCHOLASTIC LOOK

Traditionals take off! The move is to more color, more pattern, and more individuality. Mod started it; even though wide flowered ties and giraffe collars have faded from the scene, it proved that well-dressed didn't have to mean drab and dull. Stepping out at top, bold rust and blue glen plaid slacks ($18). Carrying out the colors is a shirt in another plaid ($7) and a blue heather sweater ($15). Coordinates by Puritan. Nonconformist sweater, at right, is brown with strong black and white stripes and a built-in black turtleneck. The corduroy slacks are grey. Sweater by Jantzen ($17). photo credits: top photo: Al Tosca lower photo: Hugh Birnbaum

Science on TV

The 21st Century

(Sun., Oct. 8, 6:00 p.m. EDT, CBS-TV)

The problems confronting man as he faces a life with more leisure time will be explored by Walter Cronkite in a half-hour look at "The Four-Day Week." What has made a shortened work week possible? How will people spend the added free time? What will the impact of more leisure time be on peoples' lives? What is industry doing to prepare men for this change?

Cronkite will talk with industry leaders and others in his evaluation of "The Four-Day Week."

Voyage to the Bottom of the Sea

(Sun., Oct. 8, 7:00 p.m. EDT, ABC-TV)

Admiral Nelson encounters the first mate of the legendary *Flying Dutchman* in "Cave of the Dead." A young naval officer, played by guest star Warren Stevens, boards the giant sub *Seaview* to search for four missing ships, but his mission is mysteriously connected with the first mate of the *Flying Dutchman* who is doomed to roam the Seven Seas forever.

The show was filmed at the 20th Century-Fox lot in California, where co-star David Hedison told us briefly about the new season. "We'll have a little less emphasis on monsters this year," he said, "though we'll probably feature a monster every fourth or fifth show. We try to appeal to people with a variety of interests on this series — especially to those who love the pure escapism of science fiction and the fast pace of a show which spends little time on long acting scenes."

— Peggy Hudson

Scorekeeper

(see page 24)

I. Search for the Perfect Vacuum
1.T; 2.F; 3.F; 4.T; 5.F; *6.F; *7.T.

II. Harder Than Diamonds?
1.F; 2 T; 3.F; 4.T; 5.F; *6.T.

III. Microbes at Work
1.T; 2.F; 3.T; 4.T; 5.F; *6.T.

IV. Senior Science Takes You There
1.F; 2.T; 3.F; 4.T.

Think small. If you save one person from hunger, you work a miracle. Give to CARE, New York 10016

ANSWERS TO PUZZLE

(see page 32)

C	A	V	E	R	N		F	A	U	L	T	S
R		E	A	R		B		U	S	O		A
E	X	I	T		R	I	B		A	R	I	D
T	E	N		T	I	B	E	T		A	L	I
I	R		D	O	T		R	O	D		L	S
N		M	O	N	A	D	N	O	C	K		T
	T	I								I	N	
G		M	E	A	N	D	E	R	E	D		G
R	E		O	N	E		A	C	E		M	E
A	M	P		D	E	L	T	A		R	I	O
B	U	A	L		R	I	S		L	O	A	D
E		N	A	G		E		B	E	D		E
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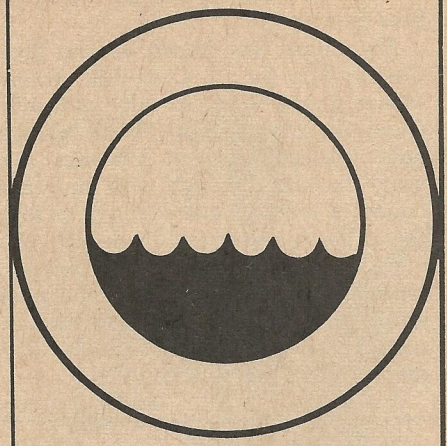

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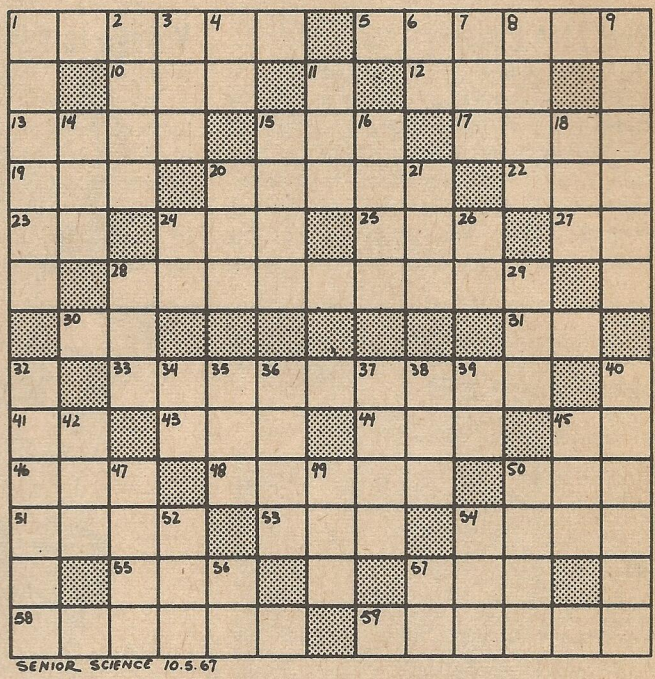
Earthwork

By Jim Bayuk, Greenwood H. S., Willard, Wis.

★ **Starred words refer to the earth sciences**

Students are invited to submit original crossword puzzles for publication in *Senior Science*. Each puzzle should be built around one topic in science, such as astronomy, astronautics, botany, geology, electronics, famous scientists, etc. Maximum of 50 words, of which at least 15 must be related to the theme. For each puzzle published we will pay $10. No entry will be considered unless it includes all of the following: symmetrical puzzle design and design with answers filled in, definitions, answers on separate sheets, and a statement by the student that the puzzle is original and his own work. **Puzzles must be symmetrical.** Keep a copy, as puzzles cannot be returned. Give name, home address, school, and grade. Address: Puzzle Editor, *Senior Science*, 50 West 44th Street, New York, N. Y. 10036. Answers to this puzzle are on page **31**



ACROSS

* 1. Chamber in a rock, formed by the action of ground water.
* 5. Displacements of rock masses along a plane of fracture.
10. It hears.
12. United Service Organization *(abbr.)*.
13. To leave.
15. A bone in the chest.
*17. Term applied to a dry, hot region.
19. A number.
20. Country in which the highest mountain in the world is located.
22. Clay's name: Mohammed _____.
23. Negative prefix.
24. A small mark.
*25. 5½ yds. of the Earth's surface.
27. Land side *(abbr.)*.
*28. Formation common to a peneplane.
30. Caligula's uncle *(abbr.)*.
31. Not out.
*33. When a river has turned in its course, it has _____.
41. Second note.
43. Undivided.
44. High card.
45. Personal pronoun.
46. Ampere *(abbr.)*.
*48. Sediment deposit at river mouth.
50. River *(Sp.)*.
51. A golden-colored Madeira wine.
53. Republic of the United States of Indonesia *(abbr.)*.
*54. All material carried by a stream.
55. Decrepit horse.
*57. Bottom of a river.
*58. Lump of native gold.
59. Instruments that measure.

DOWN

1. Person with a certain thyroid disorder.
* 2. Deposit of mineral ore.
* 3. Erode.
4. Rear *(abbr.)*.
* 6. Gold *(chem. sym.)*.
7. North American country *(abbr.)*.
8. Girl's name.
9. Person who delights in cruelty.
11. To drink.
14. Prefix meaning *dry*.
15. Woman's name.
16. Capital of a European country.
18. Not in good health.
20. 2000 lbs.
21. In addition.
24. Accomplish.
26. District of Columbia *(abbr.)*.
28. Affectedly shy.
29. Goat's young.
*32. Depressed segment of the crust bounded on at least 2 sides by faults.
34. A combining form meaning *dawn*.
35. Conjunction.
36. Not ever *(poetic)*.
37. Food *(slang)*.
38. Royal College of Art *(abbr.)*.
39. Suffix.
*40. Nodules of stone lined with crystals.
42. Ostrich-like bird.
45: Mamma _____ *(It.)*.
47. Sudden thrust of pain.
49. Recline.
50. Road *(homonym)*.
52. Fall behind.
54. Rent.
56. Gauge *(abbr.)*.
57. To exist.

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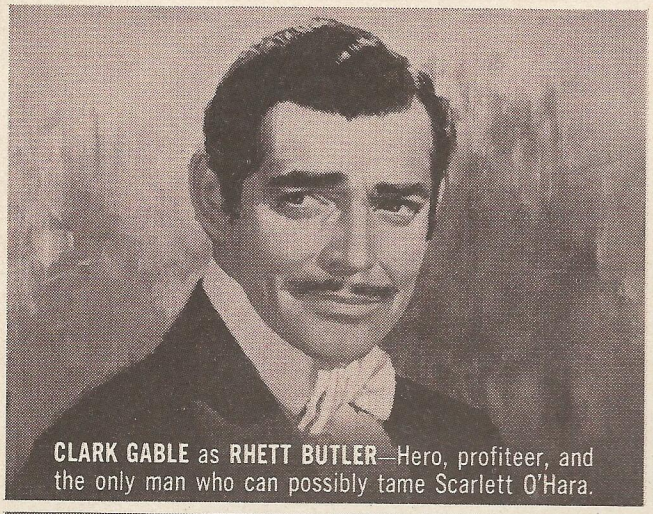
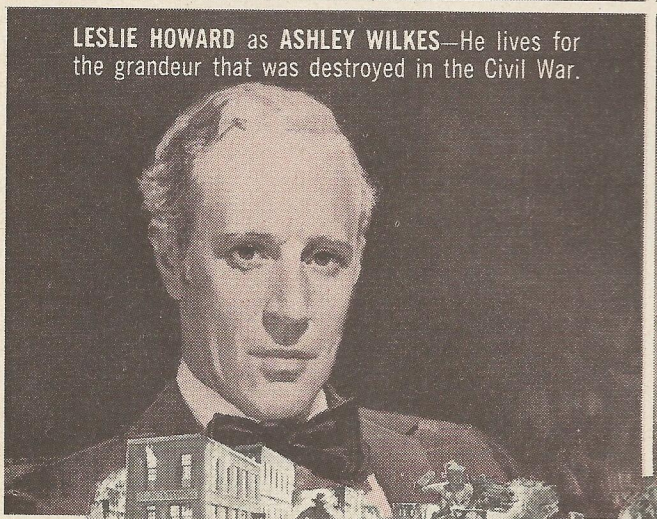


CLARK GABLE as **RHETT BUTLER**—Hero, profiteer, and the only man who can possibly tame Scarlett O'Hara.

VIVIEN LEIGH as **SCARLETT O'HARA**—She has all the spirit of a woman and all the courage of a man.



LESLIE HOWARD as **ASHLEY WILKES**—He lives for the grandeur that was destroyed in the Civil War.

OLIVIA de HAVILLAND as **MELANIE WILKES**—She sees only the goodness in other people . . . never the evil.

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